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ON THE MATERIALS AND STRUCTURE OF RIFLED CANNON.

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IN the paper which I had the honour to read before the Royal United Service Institution, in 1862, upon the subject of "Iron and Steel as materials for Rifled Cannon," the object which was then aimed at was the consideration of the several properties of the different materials that are employed in such constructions, with the view of determining and showing their relative adaptation and fitness for accomplishing successfully the extremely severe duty which they are necessarily required to perform, more especially in the interior barrel that forms the bore of the gun. In the present paper (as requested by the Institution) an attempt is made to continue the same subject; but, considered more especially with reference to the stability of the gun structure as a whole, both as regards solid and built-up guns.

As there has been so much said and written upon the gun question, it is probable that this paper may contain little in addition to what is already well known to those who take an interest in such matters, still, as I believe that the views which I hold are sound, both theoretically and practically, I offer no apology for the continuance of the former paper.

From various causes (into which it is unnecessary for me to enter the best mode of constructing rifled guns has received a large

share of attention from many scientific and practical men, and extremely different views are entertained on almost every point of detail, both in regard to the proper materials to be employed, and the best mode of combination; this has given rise to an inordinate amount of controversy, not only in Great Britain, but also in other countries, and has been followed up, to a considerable extent, by very strong partisanship. No doubt such rivalry has produced some good results, but it has, at the same time, gone far to retard the settlement of this great question.

When considered impartially, it will be found that the cardinal features of the subject are nearly definite, and that those points which determine goodness and fitness are now pretty generally agreed upon; it is, therefore, the duty of all to assist in causing such contention to cease, and to take up the subject on its own merits, without regard to other considerations. Such is the object of this paper, for my wish is to treat it merely as a matter of practical science, and without any intention of opposing or supporting those who may hold contrary views, or who may agree with me in certain details. It is, therefore, my intention to avoid all reference to the modes of construction adopted by different individuals as such, but to endeavour to point out what I consider real goodness and superiority for its own sake, without regard to its origin or priority of invention. If this much could be agreed upon by public opinion, which, in the long run, is the great arbitrator, an approach would be made towards a settlement of the best mode of making guns. And then, at a future time, it might be advisable for some one to analyse such a structure, with the view of awarding to every one concerned, his proper share of merit in regard to the invention or introduction of its several *points* of detail; each has emanated from some mental source, indeed, frequently, from many, without the knowledge that it had occurred to others previously; and it is but right that such should be done impartially, not only in justice to individuals, but as an historical record in connection with an interesting and important branch of knowledge. When the perfect gun is arrived at, its history will be like that of most other inventions, one proposing a principle, another proposing its application, and so on, little by little; but each and all have their share of merit in promoting the grand result.

I shall not refer, in this paper, to the vexed subject of the different modes of rifling. The results afforded by various systems are so nearly alike when the several conditions are the same, that it is comparatively of little importance when compared with the question of the structure of gun which is best adapted for any mode of rifling; but of the many *systems* of rifling which have been tried, there are few without some good points, and if the good points of all were studied for retention, and the bad points for elimination, free from all bias to any party, individual or country, I repeat that even that question could be settled easily with our present knowledge and experience. With the same conditions of twist, and of fit at the muzzle, and the same shape, dimensions, and balance of projectile, all will shoot alike, and that is the best, which, with those conditions, is

found to be most simple, and that injures or wears the gun the least. All can be adapted for easy loading by the arrangements adopted in some of the systems, and it would not be difficult to analyse the selected plan, and award to all concerned the part of their invention which has been adopted.

In considering such an important question as the best mode of constructing rifled guns, seeing that the soundness of the structure depends on so many conditions of material and form, it may be premised that the general principles which determine goodness are, first, permanent stability of structure, that the interior of the bore shall not be injured by the passage of the projectile and the effect of the explosion, and that it may be attainable with certainty, and, when made, shall not be too costly.

As a general principle, it may be stated that whatever materials may be employed, the most perfect way of constructing a rifled or smooth-bore gun is that in which the several particles composing the mass are so combined with regard to each other, that at the moment of explosion every individual particle shall at once take its full share of the work, and without having to wait until the yielding of the neighbouring particles enables the capacity for work in other particles to come into full play.

There is no system yet invented that comes up to this high condition, and which at the same time is satisfactory in other respects. The proposal to build up a structure with fine wire is, theoretically, probably the nearest in the one direction; but it is manifestly deficient in a high degree in the other and equally important direction, namely, the longitudinal. At the present time there is no system theoretically perfect, some are better or worse in several particulars, but in none do the several particles of the entire structure take their full share of the work simultaneously in all directions; and it will also be found, in the further consideration of this subject, that those systems which are the most easily carried out, are the furthest removed from the perfect theoretical conditions, at the same time they may have other good properties which do not belong to those systems that approach more nearly to the perfect conditions, but are yet not so simple in their construction as the former.

About 30 years ago it was discovered by the celebrated Barlow that the strength of a cylindrical mass, such as a gun, is not necessarily in proportion to the quantity of metal in regard to thickness, that mass is not strength, unless each layer of the mass is under *tension*, that in a cast or forged mass a double thickness will not afford a double degree of resistance, and that after a certain thickness any additional metal will afford very little assistance in resisting internal pressure.

There is some difference of opinion among mathematicians and engineers in regard to the amount of increase of strength afforded by the exterior mass, or rather in respect to the assistance afforded by the several laminæ of which such a structure may be considered to consist; but nearly all agree that in any homogeneous mass, such as a gun made from a solid casting or a solid forging, the outer substance of the structure has not the opportunity of rendering assistance until the

inner substance has slightly yielded, and thus by yielding, allowed the strain to pass outwards, and that even then the extreme end of the lever has only given to it an amount of work in proportion to its distance from the centre of motion. It is right to state that the precise amount of assistance thus rendered has not yet been clearly determined. Until recently it was considered to be inversely as the square of the distance from the centre of the bore; but recent investigations have thrown doubt upon that ratio, and seem to shew that it is nearer to the inverse ratio of the distance; this uncertainty arises from the experiments with different materials being so much affected by the several properties of the metals, such as elasticity, ductility, compressibility, and others, but especially elasticity; these all interfere with the result of experiment, so that the precise value of the several laminæ is still undecided; but all experiments point in one direction, that the strain is first imparted to the inner surface of the bore, and as that part of the gun is extended, so gradually the strain reaches the next stratum or lamina, and so on in succession as the laminæ are severally called into exercise.

The several laminæ in a solid mass are in a quiescent condition, and have no work stored up in them by being put under original tension, and the natural elasticity of each when considered as separate strata is not permitted to come into play, and hence the interior portion has all the more work to perform when the charge is exploded. In such homogeneous guns of whatever material, the amount of elasticity has an important influence on their stability, irrespective of the ultimate strength thereof, and also of the comparative toughness or brittleness of the metal employed, and it is found that soft stretching material, although not so strong or so good in some respects, is, at the same time, less likely to be broken up when used as the barrel of a gun, even if not under the attainable condition of support, of the better class of built up guns; but in rigid cast iron guns that have been lined in the interior with a barrel of another material, such as iron or steel, the softer and more stretchable material at the present time seems, under such circumstances, to give the best result.

In the gun which is made out of a solid block, the interior of the mass (viz., the mass that immediately forms the bore of the gun) has an inordinate share of the work to perform; this is a radical and inherent defect existing in all such homogeneous masses, and which destroys their fitness in a high degree, for it has been found that no such vessel, however thick, can permanently resist a strain greater than the tenacity of the material per square inch, out of which it is made. This, then, is a vitally important point, requiring to be kept prominently forward, and explains much of the difficulty that is daily encountered with guns, in resisting the repeated shock of gunpowder, more especially the protracted period, during which the strain is kept up in rifled guns; and from this it will be apparent that cast-iron, solid wrought-iron, solid cast-steel, or even bronze, when in a solid mass, are all so far wrong in principle, that in none of them can the several particles take their full share of the work at the moment of explosion, and unless we can find them possessed of some other redeeming pro-

perty, none form the proper material for the guns of the future, so far as the general structure is concerned.

In the construction of what are termed built-up guns, entirely different conditions are attainable; in their construction, the several laminæ are put on, or may be so, with definite tension, each hoop embracing that which is within, and each lamina under greater and greater tension in proportion to its distance from the centre, so that the work of efficient resistance is given to the several layers when the gun is first made; the inside which has so much to do, having the least tension, and so on increasing outwards, and so proportioned that at the moment of explosion, all shall do the same duty, the outer lamina, which is the end of the lever, having its equal share made up by the excess of initial tension originally given to it. By such means, the interior barrel can be so compressed by the grip of the several hoops, that the effect of the explosion affords it a momentary relief, its elasticity enables it to expand, while at the same time it is held within bounds by the outer covering, every layer being under proportioned tension, is ready and in a state of lively activity throughout, and each doing the work assigned to it, according to the position which it occupies in the general structure.

The gun structure should be such, that the several parts of which it is composed, have given to them beforehand, an amount of tension which shall be more than equal to the strain that may be brought upon them at the moment of explosion; that the total tension shall exceed the total strain to be brought upon them, and that throughout the whole structure no portion shall ever be subjected to any strain equal to the limit of its elasticity.

If such conditions are attainable, and I believe them to be so, such a gun may be expected to afford any amount of endurance, provided that a material can be found sufficiently good for the interior of the bore, so as to be able not only to withstand the local effect of the gunpowder, but to resist the wear of the ribs of the rifled projectile, upon the driving-side of the grooves. By the adoption of steel tempered in oil, this latter qualification is nearly obtained, and from the improvements daily taking place in the manufacture of steel, its final realization is probably not far distant.

It will thus be seen that to attain the highest conditions in a gun structure, extreme thinness in the hoops is the nearest approach to theoretical perfection; but in practice, the *limit* of thinness is soon reached, and other considerations step in to modify such structures and render it necessary to adopt hoops that are thicker and fewer in number; the thickness of the hoops will greatly affect the cost; the thicker and fewer in number the hoops of which the structure is composed, so much the cheaper the gun will of necessity be; and if the cheaper gun affords all that the modern requirements of the United Services demand, even although not the best in itself, it may yet be the gun for selection notwithstanding.

An approximation to the built-up gun is of course obtainable with cast or forged guns, either by boring out a part and introducing an inner tube under compression, or even in anticipation of extension, or

by removing the exterior metal and putting on hoops under tension; by either process the conditions are improved, and at a less cost than by carrying out the built-up system in its integrity; and if by such simple combinations guns are found to fulfil their function, even only in a minor degree, as regards endurance, still, on considerations of economy, it may be found that, for many situations, more especially in fortifications, such guns may fulfil all that is required, and with a moderate outlay of the nation's capital.

The very satisfactory results which have already been obtained in England by the introduction of a soft malleable iron barrel into a cast-iron gun stock, clearly show how much depends on the barrel; that it, in reality, is the gun, that the cast-iron merely restrains it from extending too far, that the strain which comes upon the cast-iron is not severe, and that it is capable of sustaining a long continuance of this strain, as an auxiliary to the more important barrel. Even still higher results have been obtained in France by the introduction of a double steel barrel inserted into an old re-bored French cast-iron service gun. The double barrel adds greatly to the assistance rendered with a given weight of steel, as it throws tension on its own exterior, and is thus the less dependent on the cast-iron; the steel was English, made by Firth, and both barrels were tempered in oil: in the case of the outer one, the tempering was combined with the shrinking, both processes being effected by the same dip in the oil cistern.

Upon the same principle, an approximation to the more perfect built up gun may be made, still better than the lined cast-iron (as much better as the material is stronger and more malleable), and in proportion to the number of laminæ that are put under tension, and as the worst wrought-iron is better than the best cast-iron, and as the layers may be made of any degree of goodness can be made, as may be found desirable, both in relation to efficiency and cost.

But either of the plans here referred to, the hooping or lining of cast-iron, or even the building up guns either of steel, or of steel and wrought-iron combined in very thick masses, may easily be overdone; and at the present time (especially when the world is unwilling to allow that any gun has yet been constructed that is good enough in all respects), it is not to be hastily recommended that in the desire after cheaper guns, any extensive departure from true principle should be followed up, without a full knowledge and experience of their permanent endurance. Let us first endeavour to get a perfect gun, that will remain intact as it leaves the maker's hands, unaffected by any charge of powder or other conditions of charge and projectile, and the possible contingencies to which it is exposed; when that has been fully accomplished, then will be the time to consider whether we shall leave well alone, or endeavour to seek after a diminution of the strength in those respects where it may be surplus in order to reduce the cost of the gun, either by using greater masses wherewith to build it up, or by the employment of an inferior and less expensive material, unless for arming fortifications, or where likely to be seldom in operation; but such a perfect gun has not yet been made, so far as I am aware.

No arrangement of structure, however, unless otherwise perfect, will yield the guns that will fulfil the requirements of the Navy; the very best that can be made for that service will still be found not sufficiently good with our existing materials, and even if the dearest guns were the best (which fortunately is not the case), the cost will be small compared with the value of the vessel; and looking at the iron-clad as a mere workshop in the construction of which a quarter of a million or more has been expended, surely it is "penny wise" to grudge any reasonable amount on good tools; for the guns, together with the quality of the material used as projectiles, are after all the only instruments to perform the real work for which the entire outlay has been incurred; it is therefore worth while investigating the conditions which afford real excellence, irrespective of cost. As I said before, the dearest are not by any means the best; real goodness, like truth, generally will be found lying somewhere between the two extremes; the built up cast steel is the most expensive, but probably it will not be found so reliable as the built up gun with a steel barrel, and the remainder of good wrought iron.

In considering different systems for the construction of guns, and the metals of which they are composed, it is necessary to keep constantly in view, not only the ultimate tenacity of the several materials, but more especially the limit of their elasticity; some metals are exceedingly low in this respect, some have a small margin of security between this elastic limit and the ultimate fracture; there can be no permanent stability where the metal is ever likely to be strained over the limit of its elasticity.

I shall divide the guns to be considered into six classes, viz.:—

Cast iron.
Bronze.
Forged wrought iron.
Solid cast steel.
Built up of cast steel.
Built up of steel and wrought iron.

1st. *Cast Iron.*—In my former paper I mentioned that after numerous experiments to ascertain the best qualities of cast iron for ordnance, the ultimate tenacity of the various samples was found to range from about 5 to 14 tons per square inch, the average being about 9 tons. This is higher than the average of the cast iron in general use, which is nearer 7 tons.

Cast iron is an impure combination of iron with carbon, in the proportion of from 2½ to 5 per cent. The presence of carbon gives softness with a certain degree of toughness; but the iron is not so close in structure, nor so strong as that containing a less proportion of carbon.

In the casting of large guns it is found that the conditions to be provided for are rather paradoxical. Where so much strength is wanted, it might be naturally inferred that we could not be far wrong in using the strongest sorts of material that could be procured; it is found, however, that such a selection would prove a failure, such guns would frequently fail at proof, for want of the toughness necessary

to withstand the vibration of the shock. On the other hand, guns cast of a softer mixture would stand the fire-proof very well, although in reality not so strong, yet from the presence of a larger proportion of carbon, they have the capability of standing, partly due to the greater toughness. At the same time these soft guns are defective from other causes, for, owing to the mass of liquid iron near to the breech, it is found that in cooling to the solid state, the core is left in a spongy condition, thus rendering that part weak which ought to be strong; the interior of a gun receiving the greatest share of the work on the explosion of the powder. These two opposite conditions of brittleness and sponginess are usually met by a compromise, and those cast-iron guns have been the most successful, that were just soft enough not to be spongy, and hard enough, consistently with the requisite toughness, not to be too brittle.

In the casting of iron guns the highest results are obtained by mixing a number of different sorts of iron together, these having been carefully and judiciously selected; such mixtures give a higher result than the average of the different sorts taken separately, but looking at cast-iron as a whole, and the chance of its not being up to the average strength occasionally, it is seldom reckoned upon as equal to more than 8 tons per square inch. As the limit of its elasticity is not far removed from the half of the ultimate strength, we have a measure of about 4 tons per square inch, as that which can be ventured up to for service; and when cast-iron is strained above the limit of elasticity it is permanently injured. Hence it is not usually considered sound engineering to try cast-iron up to that extent, and cast-iron is seldom worked up to 3 tons per inch, and by the very prudent to not more than 2½ tons per square inch.

Taking 3 tons as the maximum strain that can be given with safety to cast-iron as a permanent load, we have the measure of its capacity for work in the interior of a gun. It is now generally recognised that the strength of a gun is the resistance which it offers to tearing at the interior surface, and that, however thick it may be, it cannot permanently resist a greater strain than the tensile strength of the material of which it is made; also that the margin of safety which lies between 3 tons and the breaking-point of 8 tons is small, and that the interior is, as a rule, weaker than the outside. From being cast in a homogeneous mass, the outside renders little or no assistance until the inside has yielded to some extent; it is not, therefore, to be wondered at, that cast iron should have been found so very unsatisfactory as a material for rifled guns. In the first place, the structure is radically defective in principle, and this, with its inherent weakness, shows it to be quite unfitted for such a purpose, unless provided with an inner barrel of better material.

In this country it has been the custom, for many years, to cast such cast-iron guns as solid blocks, and then afterwards to bore out the interior to form them into guns; of late years some discredit has been thrown upon this system, on account of the change which is likely to arise in the structure by cooling the mass from the exterior, that as the outside is the first to become cold, at least cooler than the interior,

the outer ring will necessarily be contracted from the loss of temperature, and so have to stretch upon the warmer interior; but that, by-and-bye, when the inside has cooled to the same temperature, it will take up its normal dimensions, and thus lose the grip of the exterior from the circumstance of its having been stretched in the first instance. This reasoning is quite plausible, and may, to some extent, prove that guns made in that manner are even weaker than we have been supposing them to be, and these considerations have given rise to other systems of casting the mass hollow, and using means to cool the casting from the inside by a stream of air or water within the core barrel, thus reversing the conditions, and assimilating the structure to that of the built-up gun principle, with the successive layers of the structure, each gripping hard upon the layer of its interior stratum. This mode of casting is more correct in principle, and there is no practical difficulty worth mentioning to prevent its successful application; it is the plan which I would recommend, when such guns or mortars have to be resorted to, and especially when they are to be lined.

Where cast-iron guns are lined with steel or wrought iron, entirely different conditions come into play, the inner barrel having most of the work to perform, will act for itself in accordance with its capability, and being, at the least, three times stronger than the cast-iron which it replaces, will perform its duty in proportion, and the exterior cast-iron will, from the grip given to it, render its proportionate assistance to the inner barrel.

By reversing this process, viz., by leaving the cast-iron to form the interior, and hooping over with wrought iron, entirely different and worse conditions are established. Any amount of grip can be given to the interior structure, but that does not prevent the commencement of fracture in the interior, which is beyond the reach of assistance. In the case of some such guns that were enveloped in a coating of brass, the inside was entirely broken up, while the exterior remained intact.

Of these two combinations, that of lining the interior is the more correct in principle, and, as already observed, recent experiments have shewn that in practice it gives the better result; but the precise value of either depends on the absence of brittleness and the strength of the materials employed, and on the amount of grip or support which successive layers of the structure afford to those immediately depending upon them. A correct knowledge of and belief in these principles is extremely desirable, as it would prevent the useless expenditure of time and money in making experiments which can be as well determined beforehand by a careful consideration of the several conditions.

2nd. *Bronze.*—I have now to consider bronze guns. That wonderful mixture of copper and tin of $90\frac{1}{2}$ to $9\frac{1}{2}$, with the tin mixed originally in the atomic proportions with the copper, and then afterwards remelted with the proper proportions, is a metal of great value, which has long been fully appreciated by the artillerist.

Previous to the introduction of wrought iron and steel for gun purposes in modern times, this metal formed an agent of great superiority, when compared with cast iron; having considerable toughness and

closeness, possessing about double the tenacity of cast iron, and withal hard enough for the interior of smooth-bore guns, it has for centuries deservedly maintained its high character.

The great objection to its more extensive application in past times was the original cost of the metal; this alone was a formidable obstacle to its use in the construction of heavy guns, the one metal being nearly twenty times as expensive as the other. Still with all its good qualities it was defective in principle when cast as a homogeneous mass, and so far had all the inherent defects that belong to the cast iron solid block; besides, it was comparatively a soft metal when in the proportions of copper and tin which have been named, hence it was easily indented, even in smooth-bore guns, but owing to the small strain to which it was subjected by that system, it has long continued to give general satisfaction, and from its toughness has seldom or never been known to burst.

With the introduction of the rifled gun system when the full strength of the metal was called forth, the inherent defects of bronze soon began to shew its unfitness, notwithstanding its natural toughness, no doubt, a strong element in its favour, and more especially at a time when the utmost difficulty was experienced in obtaining any other metal to answer the purpose even in a moderate degree; still irrespective of the invaluable property of bronze, of not being liable to rust when exposed to the influence of wet or moisture, it is not resorted to, but chiefly on account of the expense.

Bronze is used to a considerable extent for rifled guns by some nations on the continent, and while the bearing surfaces of the ribs on the projectiles are large in proportion to the mass, so as to reduce the friction on a given area, bronze guns answer moderately well. The first symptom of failure is in the altered dimensions of the bore in the vicinity of the powder chamber, and the driving side of the grooves wear rapidly from the want of hardness, or rather from the want of stiffness in the metal, but such guns are in no danger of bursting.

The Dutch have converted a considerable number of their old smooth-bore bronze guns, by boring out a portion of the interior and lining them with brass, so as to obtain a smaller diameter of projectile, in order that the existing weight of the guns may be still of due proportion to the weight of the projectiles, which it manifestly would not be if the original bore was merely rifled, seeing that the elongated projectile is necessarily heavier than the spherical.

Taking bronze as a whole, its first cost, want of rigidity, as also, per contra, its toughness and freedom from rust, the good and the bad properties all combined, I consider that it is not the proper material to be employed in the construction of rifled guns, and that when it is used as a solid block, it is wrong in principle in addition.

Seeing that by varying the proportions of the copper and tin, bronze of any degree of hardness can be obtained, and although brittleness to a great extent will follow, yet it is possible to have such a combination, that the mixture will present many features suitable for the lining of an iron gun, provided there were no other serious objections; there exists, however, such an objection in the difference of expansibility by

increase of temperature, which brings along with it an element of destruction that renders such a combination decidedly wrong in principle. Bronze expands very nearly the double of iron; at a dark-red heat iron expands about the $\frac{1}{100}$th of its length, while bronze at the same temperature expands about the $\frac{1}{53}$rd of its length, or as ·01 per inch to ·019 per inch. In consequence of this greater expansion, the bronze under confinement, and subjected to the change of temperature due to rapid firing, would soon enlarge its dimensions by working outwards by whatever avenue of escape there might exist. In the ordinary built up gun it would be outwards at the muzzle. This is not mere supposition, for in the case of an Armstrong gun which was lined in this fashion as an experiment, the practical result fully coincided with the theoretical principles as here stated. In the case of a bronze covering these conditions would be reversed, and when warmed by firing, the greater expansion of the bronze would remove the intensity of the grip, hence the two metals are not to be combined.

3rd. *Forged Wrought-iron Guns in one block.*—In the production of the material termed wrought-iron, by the elimination of carbon and other ingredients from cast-iron, a great change is produced. At a high temperature, the metal loses its cast-iron fluidity, and assumes the viscous state, whereby the several particles of the mass are united at a high temperature by means of the well-known process termed welding. By this change, the iron assumes another character, it becomes considerably stronger and more tough; at ordinary temperatures, the limit of elasticity is increased nearly four-fold; it rises to the vicinity of 12 tons in very good iron, and the ultimate tenacity to nearly 25 tons per square inch; but there is still considerable variation in the strength of wrought-iron, depending on certain conditions in the quality, and the ultimate strength ranges from 18 tons to 28 tons, the latter description of strong wrought-iron being a close approximation to mild steel, although still retaining the name of wrought-iron, from being produced by the iron making process of refining, puddling, and careful working.

Wrought-iron is seldom entirely free from carbon, and the quantity may be said to vary from purity up to $\frac{1}{4}$ per cent. The presence of a small quantity of carbon, while increasing the strength and the rigidity of wrought-iron, at the same time interferes with the welding property, hence the strong steely iron is more difficult to work into sound structures than the weaker sorts, owing to this defect; and from this circumstance arises the constant effort to employ steel for purposes where a steely iron has hitherto been employed, not only for guns, but also in railway tyres, and for similar purposes.

In the building-up of large masses of wrought-iron, in order to form a solid gun, of necessity the mass is made up of innumerable small particles, which have been gradually collected and united, first into lumps termed "blooms," then into larger slabs, until at length the ultimate dimensions are obtained. As a sound weld is entirely dependent on the purity and temperature of the surfaces, any dirt or impurity will frustrate the attainment of sound welding; it is manifest, therefore, that the forging of great masses is surrounded with many

difficulties, which until recently have prohibited the use of this material for guns.

The invention of the steam hammer has done much to develope the production of large forgings, and the high results afforded by the celebrated Mersey gun, show that it is quite possible to produce them. This gun weighs upwards of 20 tons, with a bore of 13 inches diameter, and is a splendid forging.

But there still remains the fact that the chances of defective welds are extremely numerous, and even in the great gun referred to, there is a cleft in the powder-chamber, which would not be admissible in the ordinary guns of the service; and at the present time, to all appearance, we are still far removed from being able to forge large wrought-iron guns with absolute certainty of having them perfect in every respect, more especially in the bore and powder-chamber.

A wrought-iron solid gun, if moderately perfect, is much superior to a cast-iron gun; at the same time, the chances of the former containing defects are considerably greater than the latter, in the formation of which, the fluid iron runs into a closer structure, and, all its grosser impurities have had the opportunity of floating upwards into the dead head, and of thereby being eliminated from that portion of the casting which is to form the gun; in forging wrought-iron, however, the impurities are frequently enclosed, without any means of escape; hence they form defective lines in the structure.

As in solid cast-iron and solid bronze, so in a solid wrought-iron forged gun, every particle of the structure is not in a condition to render its full measure of work, the strain must first come on the interior, and gradually extend outwards; still, if guns in a single block could be produced with certainty, so far as relates to perfection in the bore, and otherwise capable of withstanding the effect of continued firing, similar to that of the large Mersey gun, they would be fully appreciated, and probably preferred by many to a gun built-up of a number of detached pieces, even though the latter is theoretically more correct in the general principle of construction. But judging from recent experience, it does not seem likely that solid wrought-iron guns will come into general use. Solid steel guns, or some modifications of built-up guns, are much more likely to afford the results required by the modern artillerist, and solid wrought-iron guns are not such as I can recommend.

4th. *Solid Steel Guns.*—Looking at wrought iron as a metal composed of iron and carbon from purity up to a quarter per cent., with the several inherent defects of unsoundness, dross, and imperfect weldings, if this same wrought-iron could be readily melted, so as to eliminate its bad qualities, and to retain all the good, especially the tenacity and the toughness, it would then be a material for gun purposes difficult to surpass, and which would fulfil every condition.

This, however, is not easy to accomplish, and we find that the purer the iron is, so it is all the more refractory in the melting-pot.

Iron, with the addition of carbon, becomes steel, and steels vary in carbon from about $\frac{1}{4}$ per cent. to $1\frac{1}{4}$ per cent. Above that the steel

becomes hard and brittle, gradually degenerating to the quality of cast-iron, even up to 6 per cent.

The more carbon which is contained in the mixture, the easier is it melted; hence the first cast steel gun was of the high carbon quality, but during the past 50 years a continued improvement in this respect has been going on, and now steels can be melted down almost to a quality resembling the more steely descriptions of wrought-iron.

The steely iron has an ultimate tenacity of about 28 tons per inch, and these mild steels about 30 tons, and with the higher mixture of carbon even up to about 70 tons; from this it gradually sinks to the lower qualities of cast-iron down to 5 or 6 tons per square inch.

The advantages of steel over wrought-iron are in most respects very great: compactness, closeness, and the perfection of its general structure, together with its high tenacity, all commend it as the best material for the interior of a rifled cannon. The radical defect of cast steel when in great masses is the want of toughness. Even in steely iron this is conspicuous, but it is still greater in cast-steel; and as the quality of the steel becomes higher it is usually followed up by a gradual diminution in the toughness.

Guns composed of puddled steel by forging, that is, by being manufactured like wrought iron, but only left more steely by extra carbon, are exposed to all the worst defects of wrought-iron, without the redeeming quality of extra toughness. Solid cast steel, on the other hand, opens up a field much more encouraging, and from the marked success which has already been attained with this metal, there are many who look forward to it as the ultimate material for large guns. Past experience has led me to a different conclusion, because, to use it like cast-iron and solid wrought-iron is wrong in principle, although it has four times the strength of cast-iron, still the gun made of it will be acted upon in detail, and from this cause, combined with a want of toughness, and the uncertainty of the material, it will occasionally burst without warning.

If there were no other resource open by which a reliable gun could be made, it is probable that by continued improvement in this metal, it might ultimately be found to answer; but the expense, when in great masses, is nearly equal to that of copper, which is a formidable objection, although secondary to the other considerations. As a lining for large guns, steel is wonderfully perfect, still it is not to be trusted by itself unless backed up by a tough envelope in layers, each layer being under more and more tension, and so combined that if the steel gives way there is no danger to the men who work the gun, or to the bystanders.

5th. *Built-up Guns of Steel, or of Steel and Wrought Iron combined.*— In the previous remarks on different descriptions of guns, the object has been to point out reasons why they are not suitable for the required purposes of modern artillery, but in those which are to follow, the object is to explain the built-up gun. Guns of this class are now variously constructed, and with different degrees of excellence. I shall endeavour to point out that which I consider the best, and which I believe is sufficiently good for the requirements of artillery at the

present day. At the same time, the best built-up gun will not come fully up to the high theoretical conditions of perfection which have been referred to. Its every part will not be found to take its full share of the work at the time of explosion, for in the best guns yet made, these conditions are not reached; still an approximation is attained with a greater or less degree of success.

There are many who strongly advocate a built-up gun entirely of cast steel; that the steel is confessedly the strongest metal, and the best in all respects, and that when tempered it is tough, sound, and reliable, and hence that such a structure, as a whole, must be better than if only the inside is of the high quality, and the remainder of an inferior and less rigid material, such as wrought-iron, or even cast-iron; that by combining metals of different degrees of expansibility and rigidity, there must be a want of that homogeneity which is attainable only with one description of material. There is great force in these arguments, and I believe such a gun, if properly put together, will be the best (so far as strength is concerned) that can be made. Still, notwithstanding its numerous high qualities, I do not consider that, as a whole, it will be found so reliable on actual service as the more humble structure, with steel forming the inside, and wrought-iron the remainder. When really good and tough throughout, the entire steel will have the greatest endurance; but until we can have more confidence in that metal, there is greater risk of occasional fracture when guns come to be made in great numbers; besides, the expense of the one metal over the other is so considerable, that it would require even still greater superiority than it now possesses, before it could compete successfully with the equally serviceable gun made by a combination of the two materials.

The principle of building up guns is much the same, whatever may be the material employed; the gun consists of hoops, put on over the interior portion, each in succession being under tension, this tension being produced either by warming the hoop so as to expand its dimension, or by using hydraulic force to push a slightly tapered hoop over a part prepared with a corresponding taper, and of the suitable dimension calculated to give the necessary tension. Such a mode of construction as the latter, demands extreme refinement of fitting to carry out successfully; but if the workmanship is sufficiently accurate, it will afford good results, although so far as I can judge, not commensurate with the expense.

The mode of construction which I consider the best is a combination of steel and wrought-iron, steel to form the inside, with wrought-iron hoops put over it for the remainder of the structure, but without any serious objection to the trunnion-piece being of cast-iron, where economy is an important consideration; such a combination will give more work for a given sum of money than any other plan.

Plate XXXI, fig. 1, represents in section the general structure of built-up guns, such as I consider the best where cost is not of paramount importance. The same gun, with a cast-iron trunnion-piece, a little stronger and slightly modified, would be nearly as good, and a little cheaper. In its general characteristics it resembles the mode of construction now practised in the Royal gun factories at Woolwich,

Fig. 1.

Bu

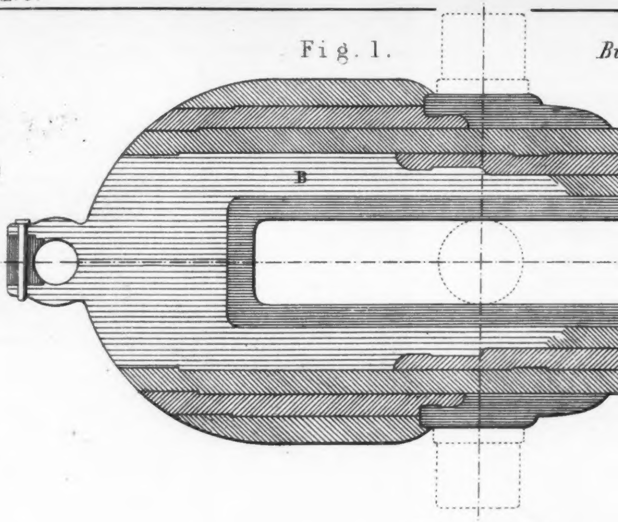
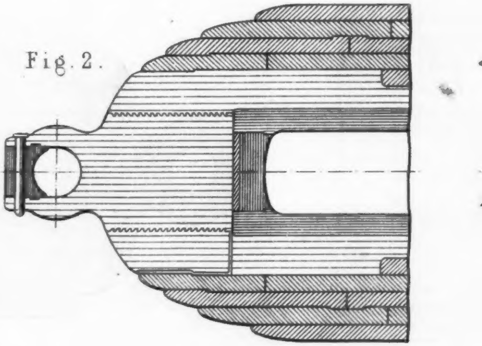
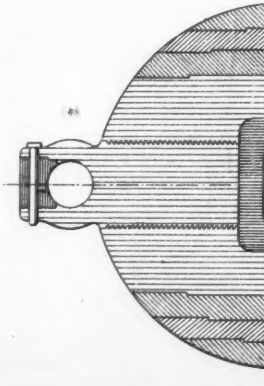


Fig. 2.





Methods of Closing
the Breech.

Fig. 2. *Sir Wm. Armstrong's.*
Fig. 3. *Mr. Whitworth's.*
Fig. 4. *Plan to obviate defects in a Solid Forging.*

Built up Gun, with Steel Core and wrought Iron Hoops

Dia.r of Bore ..... 13 in.s
Length of Bore .. 145 in.s
Weight .... 25 Tons.

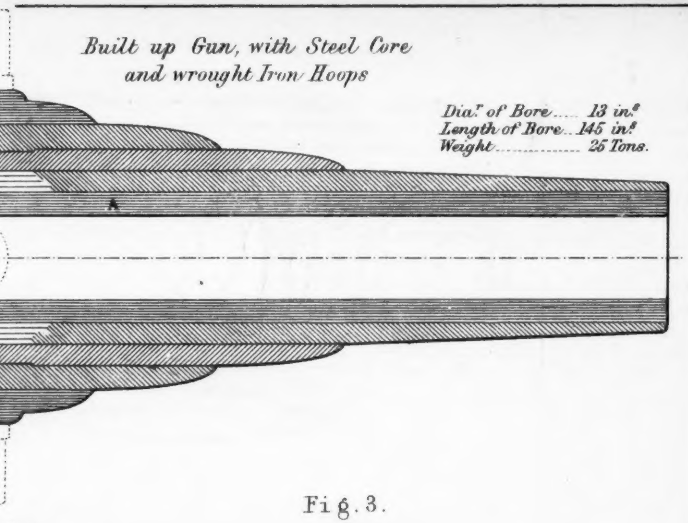
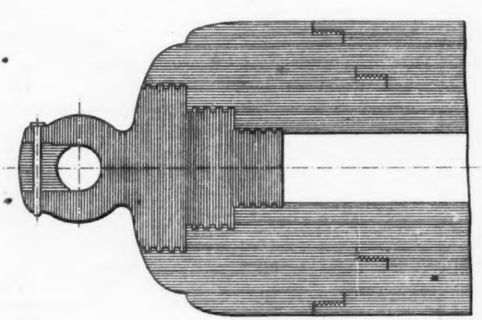


Fig. 3.



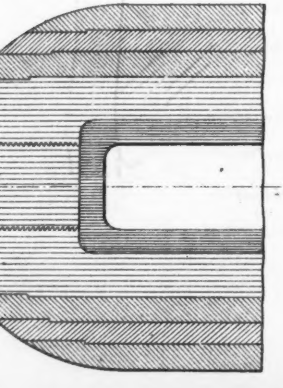


Fig. 4.

J.R.Jobbins

but the lines are not those of the Service pattern, and it differs in some other respects; it is nearest to the construction of the piece of ordnance called the "Frederick" gun, but considerably larger; that gun has a bore of 7 inches in diameter, while that in the diagram corresponds more with the 600-pounder size, the bore being 13 inches in diameter. Its leading features are the solid end to the steel inner barrel, a solid end on the breech-piece to support the barrel, the absence of a breech-screw, the system of holding the structure together longitudinally by raised steps or shoulders on the several hoops, and breaking the joints by overlapping.

In a general way, the built-up guns, as at present constructed, consist of an inner barrel, made of iron or steel, covered with a series of hoops, one over the other, each in a state of tension, so combined that the total tension shall exceed the force of the explosion. The leading feature in building up, so as to insure a permanent structure is, that the initial tension should be such, that, in addition to that given by the explosion, it shall not be equal to the limit of elasticity in the materials, which, in the case of iron hoops, is not on the average, much above 10 tons per square inch. This gives a margin of strength fully more than that amount before ultimate rupture ensues.

In the qualities of steel employed for guns, the limit of elasticity is about 13 tons, but when tempered in oil it rises to about 32 tons. The ultimate strength is, in the untempered state, about 33 tons, and tempered in oil about 52 tons, but sometimes a little over, and sometimes a little under, according to quality. This remarkable increase of strength given to the mild qualities of steel by the oil-tempering process, is also accompanied by a considerable amount of toughness, and also elasticity, which is of great importance. A load of 30 tons per inch will cause it to stretch $\frac{3}{1000}$ths of an inch before it begins to elongate permanently, and this stretching may be given an indefinite number of times without any sensible lengthening when the load is removed.

In my former paper I pointed out the several advantages of steel for the inner barrel of rifled guns, and gave a forecast of the qualities that the world was waiting for. Since that time the required quality has been almost realised, and is, in a great measure, due to the advantages arising from the oil-tempering process, together with the improved quality of the steel now supplied by the firm of Firth and Son, of Sheffield.

Figure 1 represents a section of a built-up gun, with a tempered steel inner barrel, and constructed on such arrangements as will probably afford the best results. The substance of the steel barrel A is nearly uniform in thickness, namely, $3\frac{1}{2}$ inches; the only exception is at the breech end, which is $4\frac{1}{2}$. It is preferable to have the breech thicker than the cylinder, although the objection to such a difference of substance arises from the tendency to unequal contraction when the red-hot mass is plunged into the cold fluid, thereby tending to induce flaws which may afterwards be developed by the firing. The barrel is close at the breech end and is formed out of a solid block by boring to the required depth.

There is some difference of opinion with regard to this solid breech,

that it is not so reliable as an open tube afterwards plugged up, that the latter is not so likely to be ruptured, and that such a plug can be made sounder and better adapted for its work than can be done in forging a great mass of steel, where there is a tendency for the centre to be unsound. An inference has been drawn unfavourable to the solid end, from the circumstance that some guns made on this plan were found to waste rapidly in the centre by continued firing; but a series of experiments made to test the quality of the metal, of a slice cut from the gun which wasted the most, has shown conclusively that there is no appreciable difference in the quality of fourteen specimens cut from all parts of the surface, that across the centre being equal to the outside. The wasting alluded to arose from the parabolic shape of the extremity of the powder-chamber, causing a convergence of an intense flame, which, acting like a blow-pipe, had the effect of eating into the centre, and which has been obviated by flattening the end of the chamber, as shown in the diagram, thereby distributing the flame over the whole surface.

In the construction of guns with a plugged barrel, Sir William Armstrong provides for any accidental escape of gas past the plug, by the introduction of a small vent or passage behind, in order to prevent the full force of the explosion from exerting undue strain on the larger area of the breech-screw. Such a passage can do no harm, and when the leakage is not large, it may be beneficial; by others this provision is considered unnecessary.

Figs. 2 and 3 show the mode of closing adopted by Sir W. Armstrong and Mr. Whitworth. As the Woolwich guns are on the solid plan, time and experience will show which is the best.

The part of next importance to the barrel is the breech-piece B, Fig. 1, it is made of wrought iron, with the fibre and welds lying longitudinally. In the diagram it is shown sólid at the breech, resting hard upon the end of the barrel, and giving all the aid of which the material is susceptible, and at the least expense. While believing this to be the most simple and best arrangement yet proposed, still there are many whose opinions are of great weight who do not concur in the arrangement, and consider it inferior to the plugged barrel held in check by a breech-screw, believing that the latter mode better provides for defective workmanship, and is more likely to give a sound and firm support to the material at the extremity of the barrel. According to my view, a perfect gun should have no contingencies of parts moving to provide for, but should leave the maker's hands in such a condition that no point will be exercised up to that amount of strain which will exceed the elasticity or produce any alteration whatever.

In the arrangement shown in Fig. 1, the breech-piece is made out of a solid block of wrought iron bored out to a size smaller than the barrel, with a difference of dimensions that will throw a strain of about 6 tons per square inch upon the iron, the ends of the barrel and bore are flat, both being perfectly true to each other, so that when pulled hard, the bearing of the barrel on the breech-piece shall be equal and uniform over the entire surface.

In order to place the breech-piece upon the barrel, the former is made

red-hot, which causes it to enlarge in diameter and to become longer, and it can thereby be put on with the utmost facility. At a red heat the iron elongates about $\frac{1}{100}$th of its length, advantage is taken of this by causing the extreme, or open end, of the breech-piece to grip hard upon the barrel by the application of cold water, while the remainder is still red-hot and consequently long; as it gradually cools it also shortens, and being hard home at the breech, it of necessity has to drag the open end which grips along the barrel, and, by-and-bye, it is gripping hard along the whole surface, so that before it settles, the two surfaces at the breech are hard home, with the metal of the breech-piece under considerably greater tension than could be obtained by any screw pressure.

It has been objected to this system, that as the centre of the breech-piece is liable, like all other large forgings, to be unsound, such unsound or defective surface cannot render the same support as sounder metal. There is some truth in this objection, where the breech-piece is found defective; and the arrangement shown in Figure 4, is a method of overcoming it, retaining most of the good points of Figure 1. In this arrangement, the barrel butts hard against the solid breech-piece, on a surface equal to its own thickness, leaving only the centre unsupported, which support is afterwards given by a screw, as shown; this affords perfectly satisfactory results, but it is not so sound as the other, and is more expensive. By either method, the inner barrel is firmly bound in all directions, and exists under great compression, both circumferentially and longitudinally, and the amount of grip can be ascertained by the after dimensions, an elongation of $\frac{1}{10000}$th part being equal to a tension of one ton.

In the hoops employed for building-up the remainder of this gun, with the exception of the trunnion, which is made by forging in the usual manner, the Armstrong system of coiled iron is employed, it is cheaper than cast steel, and although not so strong in point of tenacity when compared with that material, yet it has great toughness and may be relied on with the utmost security. I believe, for these reasons, it will ultimately have general adoption. I consider that steel is too expensive a metal to employ except for the inner barrel.

Of the best description of iron to be used in the construction of coiled hoops for such large guns, it is desirable that the cheapest, consistent with the requisite quality, should be employed. Wrought-iron is made of all qualities, and at all prices, from about £7 10*s.* per ton up to £28. But while it so happens that each sort has its own peculiar value, and is prized for some of its properties, and the price paid accordingly, still it does not follow that the dearest is the strongest, nor the cheapest the weakest. The high price is frequently due to the labour spent in refining to a high degree of purity or closeness, and a much lower quality may have an average strength suitable for the outer structure of built-up guns.

In the earlier guns, and indeed up to a recent time, the Yorkshire quality of iron was chiefly used; but the cheaper iron of Staffordshire and other places is now being substituted. It is one of the characteristics of the steely iron of Yorkshire, that it welds reluc-

tantly, as compared with the lower qualities; where there is so much welding, this is a point of great importance, and taken together with the lower price, will tend to reduce the cost. Another question which affects the cost is the thickness of the hoops. If the principles already alluded to are correct, it follows that to obtain the best results from the metal employed, the laminæ should be as thin as practicable; but such thinness can only be secured by increased expenditure in the manufacture, hence the question arises as to the limit of substance to be employed consistently with the due preservation of the inner barrel, which is in reality the gun. Time and increased experience will determine this point, and it may yet be found, that the remainder may be all in a single coil, in the construction of which there will be no practical difficulty, if it is found to answer the required purpose of holding the barrel entire.

In order to lock or bind the component parts of the gun together, it will be observed that a system of longitudinal hooking is employed. This is effected by taking advantage of the enlargement of the one coil by heating and thus passing it over, as it cools it pulls up hard against the shoulders. In the same manner the breech is further supported by the coiled hoops, thus all the parts tend to tie the gun together in every way.

As the greatest strain will come on the layers nearest to the barrel, and as also the grip of the outer coils will tend to undo a portion of the grip of those under them, these conditions have to be considered in determining the tension to be given to the several laminæ, and it should be such that in no case is the limit of elasticity overcome. If that takes place, especially in the outer hoops, then the gun is virtually injured, for such parts cease to perform their duty until the others under them are distended sufficiently to overtake their intended supporters.

In my former paper reference was made to the improvement which takes place by the process of drawing iron into wire. Iron of 25 tons will rise to 35 tons. In this direction lies a field for the improvement of coiled hoops, and as the manufacture advances it is probable that rolling until the iron is black will be resorted to; this will enable the hoops to be worked economically almost to finished dimensions, and at the same time increase that most desirable property which exists in wire, and otherwise improve the quality of the iron.

With the wrought iron in its natural state, as at present employed, a tension of 6 tons per inch is a safe load to leave upon the hoops next to the barrel: in this state they are exceedingly lively, both in giving support and in taking assistance, and they are in a condition to bear an enlargement of $\frac{4}{1000}$ths of their diameter, without going beyond the limit of their elasticity. Such enlargement, being so well supported, if it should take place from permanent extension of the barrel, will not be so disadvantageous to the entire structure as when it occurs nearer the exterior. A little extra pinch is given to those next in order, and about 8 tons to the outermost of all, this gives a margin of $\frac{2}{1000}$ths of its diameter to play with, besides all the strength which lies beyond, before ultimate rupture takes place.

When a gun is put together in this manner, the whole structure is in a lively condition; each lamina is ready to do any extra work, though already loaded with the full duty which it ought to perform, and with even more than what is complementary to the effect of the explosion; and while the inner barrel remains intact, it may be expected to last for an indefinite period.

Evening Meeting.

Monday, May 29th, 1865.

Rear-Admiral Sir F. W. E. NICOLSON, Bart., C.B., in the Chair.

NAMES of MEMBERS who joined the Institution between the 15th and 29th of May, 1865.

LIFE.

Salkeld, J. C., Lieut.-Col., late Indian Army. 9*l*.

ANNUAL.

Sargent, J. M., Col., C.B., Half Pay, 3rd Buffs. 1*l*.
Chichester, Geo., Lieut., late 6th Regt.
Reed, A. T., Capt., H.M. 10th Bombay, N. I. 1*l*.
Bowdich, E. H. S., Lieut.-Col., H.M. 26th Bombay N. I. 1*l*.
Edmonds, Henry, Staff-Surgeon, R.N. 1*l*.
Oldham, W. H., Lieut., 48th Regt. 1*l*.

ON "UNSINKABLE OR RAFT SHIPPING."

By CHARLES ATHERTON, late Chief Engineer, Royal Dockyard, Woolwich.

THE aggressive powers of ordnance versus the defensive powers of iron armour plating still constitutes, after years of experience and millions of expenditure, an inquiry, the solution of which fluctuates with every alternate test of their relative capabilities. The introduction of armour plating induced improvements in ordnance; the iron-sided floating batteries, which successfully withstood the fire from the Kilburn Fort in 1855, originated and succumbed to the more effective gunnery of 1859. The resisting power of armour-plating was consequently increased, and the $4\frac{1}{2}$-inch armour of the "Warrior" was for a time regarded as invulnerable, until the gunnery of 1862 sent both shot and shell through the then most approved model of the "Warrior" target. Attention was then directed to improving the quality of the iron which constitutes the armour plating of ships. The relative efficiency of hammered plates, as compared with rolled plates, was duly investigated, and in the lately launched ship ("Bellerophon") the thickness of the armour-plating has been increased to 6 inches, with an inner plate of $1\frac{1}{2}$, making $7\frac{1}{2}$ inches; but now, again, guns throwing shot or shell of 320 lbs. weight are found to prevail, and consequently the "Hercules," now being laid down at Chatham, is said to have been designed to carry armour-plating of the aggregate thickness of 9 inches,

but guns to carry shot of 600 lbs. weight are also being prepared, and 1,200-pounders are said to be in contemplation, and with little doubt of their being successfully introduced, for the whole matter of practical gunnery, as respects the required quality of materials and the relative proportion of parts to produce any desired effect, is now prosecuted on principles based on the ascertained laws of progressive increase, whereby it is confidently expected that guns may henceforth be constructed of the required capabilities for penetrating any armour-plating of which the thickness may have been determined upon. In short, practical gunnery seems now to have become one of the exact sciences in the prosecution of which, with a view to the attainment of any given result, there is no limit but cost. But this is not all. We have hitherto aimed at rendering only the sides of ships invulnerable, and granting that we may attain that end, what of it? What is there to prevent mortar practice being revolutionized, as has been the case with gunnery? Ships may thus be assailed by a new era in mortar practice hurling down thunderbolts from above, smashing the deck, carrying all before them, and passing through the bottom of the assailed ship. No construction of vessel has yet been devised to meet this mode of attack, so manifestly possible, and therefore so probable, and which, whenever adopted, will again necessitate the reconstruction of our ships of war. Whilst thus threatened from above, we are also threatened with being assailed from below. Ships are now being constructed with submerged peaks for bursting through the sides of vessels below the level of the armour belt—a foul blow insidiously applied, yet lawful by the code of relentless naval honour. Then, again, the possible introduction of the steam ram, with monstrous powers of collision, combined with explosion, is not to be ignored. Now, I ask, how are the effects of these aggressive forces to be met or averted? and in reply I propound the question—may not the principle of raft-like unsinkability be combined with the partial protection afforded by armour plating, by which combination the guns, mortars, and rams of our opponent may do their worst, but still our vessel shall not sink? By this device there may still be some chance of hostile ships being lashed alongside each other, and victory determined not by the fire of guns, or the bullying of the ram, but by the arbitrament of hand-to-hand personal prowess.

My purpose, therefore, on the present occasion is, in the first place, to bring forward for our review those elemental bases, a knowledge of which is necessary in a practical point of view, to our due consideration of the question, whether resistance by armour-plating being supplemented with the introduction of the principle of "unsinkability," does not afford the most available means as applied to ships of war for mitigating the horrors that may otherwise result from the destructive powers of modern ordnance and modern device, consequently whereon it has already been publicly avowed, that hostile ships of war will scarcely be able to approach each other without one or the other being sent to the bottom. In pursuance of these views I proceed—

1st. To explain the theoretical principle of procedure by which, as distinguished from other plans, I propose to effect the object of pre-

serving ships afloat, notwithstanding the penetration of shot or shell through the sides, deck, and bottom of the ship.

2ndly. To give the theoretical elements, data, and calculations on which the efficacy of the proposed system is based, and show by drawings the general mode of practical construction by which the principle may be applied to mercantile shipping and to ships of war.

Various devices have from time to time been adopted for mitigating the danger of sinking, to which ships, and especially steam ships, are liable from the occurrence of leakage, rupture from striking on rocks, collisions with other vessels, derangements of machinery, and other accidental causes. These devices have hitherto consisted in dividing the ship into compartments and cellular divisions by means of water-tight bulkheads. Also, in constructing the ship with a double skin or shell, and dividing the space between the two shells into water-tight cells. These devices afford great protection against ordinary casualties, which usually occur singly and affect the ship only at one spot; but such cases are not analogous to the dangers resulting from the repeated and continuous damages from shot and shell to which ships of war are exposed in action, and whereby all parts of the ship may be penetrated, lengthways, crossways, and vertically, through and through, in the course of a single hour. Several such compartments or cells may be penetrated by a single shot and become immediately filled with water, and this being repeated, the buoyancy of the ship becomes gradually reduced, till she ultimately sinks. This system of cellular air spaces may greatly mitigate the danger of sinking, and prolong the floating of the vessel, but it cannot be said that such ships are unsinkable by shot.

The system which I propose may be denominated the solid raft-system, to distinguish it from the hollow cellular system, above referred to, and it consists in combining with the structure of the ship such a quantity of solid and non-absorbent materials, lighter than water, as shall support the whole weight of the ship and its load, whereby the vessel shall not sink, though perforated in all directions by shot and shell, or cut down by the stroke of a hostile ram.

Theoretical Elements.—The practical construction of raft shipping with a view to carrying out the principle of "unsinkability," must evidently be based on calculations involving the weight or specific gravity of the materials of which the floating body is to be composed, with reference to the weight or specific gravity of the fluid on which it is intended that the vessel shall float, and which, in this case, we will assume to be fresh water, which will give about 2·4 per cent. of the displacement in favour of the buoyancy of the vessel when floating in ordinary sea-water. That is, a ship which would carry, say 1,000 tons weight, on a fresh-water river, will, at the same draft, carry a load of 1,024 tons weight at sea; and the materials used for shipbuilding being, as respects their specific gravity, of a fluctuating character, dependant on their quality and condition, it follows that different authorities have not always assigned the same specific gravity to timber of the same denomination. The following table is, therefore, annexed as the basis on which the results put forward in this paper have been calculated:—

Materials.	Weight of a cubic foot.		Relative sp. gr.
	Ounces.	Pounds.	
Fresh water at 60°	1,000	62½	1,000
Sea water	1,024	64	1,024
Wrought iron	7,760	485	7,760
Seasoned oak	800	50	800
Teak	704		
Honduras mahogany	704	44	704
English elm	704		
Seasoned red pine	656	41	656
" larch, and			
" yellow pine	560	35	560
" white pine	448	28	448
" poplar	400	25	400
" cork	192	12	192

Now, as the weight of any floating body is equivalent to the weight of the quantity of fluid displaced by the floating mass, it follows that the load which will be supported by a cubic foot of any material of less specific gravity than water, when floating on water will be equal to the weight of a cubic foot of water less the weight of a cubic foot of the floating material; consequently, from the foregoing table, we at once deduce the weight that would be supported by each cubic foot of the different materials referred to in the table, when immersed in fresh water, weighing 62½lbs. per cubic foot. For example:—

			lbs.
Each cubic foot of	oak	will carry a load of	62½ − 50 = 12½
" "	teak, mahogany, elm	"	62½ − 44 = 18½
" "	red pine	"	62½ − 41 = 21½
" "	yellow pine	"	62½ − 35 = 27½
" "	white pine	"	62½ − 28 = 34½
" "	poplar	"	62½ − 25 = 37½
" "	cork	"	62½ − 12 = 50½

Hence we deduce the following table, showing the number of cubic feet of each of these materials which, if used as the buoyant material of raft shipping must be employed to support each ton weight of load with which it will be burdened.

For each ton weight of load there will be required as follows:—

	Cubic feet.
If oak be used as the buoying material	179
" teak, " mahogany, " elm	121
" red pine	108
" yellow pine	82
" white pine	65
" poplar	60
" cork	44·36

Thus it appears that the advantages of cork as compared with oak for the floating material is as 179 to 44·36, or about 4 to 1, as respects quantity to be employed for supporting any given load, and as 80 to 4·8, or about 16 to 1, as respects the weight of material for any given load. But cork, or any other material of the same specific gravity as cork, may require the support of some bonding material to give it the solidity which is desirable for its constituting the buoyant material of raft shipping. It is probable that cork and timber may be advantageously built into the ship in alternate layers, whereby a light compound mass, well bonded together, may be formed. The results shown in the following table will therefore be useful:—

Table showing the proportions of cork and different kinds of materials which will form a compound mass of one-fourth the specific gravity of water, the specific gravity of the various materials being taken as shown in Table **A**:—

Compound materials.		Proportional quantities.		
Cork and wrought iron	..	1	to	·0077
" oak ..	..	1	"	·105
" teak	..	1	"	·128
" mahogany	..	1	"	·128
" elm ..	..	1	"	·128
" red pine	..	1	"	·143
" larch	..	1	"	·187
" yellow pine	..	1	"	·187
" white pine	..	1	"	·293
" poplar	..	1	"	·386

It thus appears that a compound mass one-fourth the specific gravity of fresh water may be formed by combining

			Cubic feet.		
	10 Cubic feet of	cork with	·077	or 37 lbs. of iron	
or	"	"	1·05	cubic feet of	oak
"	"	"	1·28	"	teak
"	"	"	1·28	"	mahogany
"	"	"	1·28	"	elm
"	"	"	1·43	"	red pine
"	"	"	1·87	"	larch
"	"	"	1·87	"	yellow pine
"	"	"	2·93	"	white pine
"	"	"	3·83	"	poplar

Hence we see in what proportions of thickness alternate layers of cork and other materials may be used to form the buoyant material of raft shipping, such that the average specific gravity of the mass shall be only one-fourth of the specific gravity of water. For example: a layer 10 inches thick of cork, or other material of the same specific gravity, may be alternated with ·08 inches of iron, or 1·05 of oak, or 1·28 of teak, mahogany, or elm, or 1·43 of red pine, or 1·87 of larch or yellow pine, or 2·93 of white pine, or 3·83 of poplar.

Whence it appears that if cork at 12 lbs. per cubic foot, or other material of the same specific gravity as cork, be used for our buoyant material, every cubic yard of such material may, when built into the

ship, be bonded together with 100 lbs. of hoop-iron, producing a well-bonded mass of buoyant material, of which the specific gravity will be one-fourth that of water, and of which each cubic foot weighing 15·625 will carry a load of 46·875 lbs.

Seeing now, from the foregoing tables, the great advantage of employing substances of light specific gravity as the buoyant material, it will become important to ascertain what substances or preparations of material will be available for the purpose referred to. There are many vegetable productions of tropical growth of a specific gravity nearly the same as that of cork, which productions may, like cork, be so prepared and manufactured as to form masses or blocks, of any definite size, convenient for being built in layers of definite thickness, into the hold of a vessel, and so chemically treated as to be uninflammable, such masses, manufactured by the aid of machinery, may be produced at probably a cheaper rate than cork, and be equally serviceable.

Moreover, as an example of manufacture, small boxes of suitable dimensions, for being laid by hand, like bricks, may be formed of white pine, poplar, or other light wood, which would constitute a cellular mass of extremely light specific gravity, and which, if used in those parts of the ship least exposed to shot and shell, would be available for forming the buoyant medium of raft shipping. It is, therefore, suggested that if premiums be awarded for the discovery and production of buoyant materials, whether in their natural condition or manufactured suitable for the purpose referred to, a choice of such material would be produced whereby dependance on any one kind would be obviated, and various materials fit for the purpose would be supplied at their fair market value, based on the cost of production. The specimen of buoyant material submitted herewith, six inches square and three inches thick, weighs 10 ounces, being at the rate of 10 lbs. per cubic foot, or about one-sixth the specific gravity of water; consequently, we may calculate on the buoyant material for raft shipping being prepared and cemented in place at the average weight of 15·625 lbs. per cubic foot, being one-fourth of the specific gravity of water. The buoyant power of such material will be 46·875 lbs. per cubic foot, exclusively of its own weight, and each ton weight of burden will require 47·8 cubic feet of such material, and the weight of the material itself will be at the rate of 143·36 cubic feet per ton weight.

Practical Construction.—We now proceed to explain the practical construction of raft shipping with reference to its buoyant properties, such being necessary to enable us to arrive at some definite conclusion as to the mercantile effectiveness of such vessels for carrying weight of cargo with reference to their size as expressed by displacement, and also to determine in the case of gunboats and ships of war the definite weight that can be allowed for armour-plating, with reference to the size or load displacement of the ship, whence the extent of armament and ammunition which the ship can carry may be deduced, for it is presumed that the guns and crew of such vessels should be fenced in by armour-plating equally with their opponents, protection from sink-

ing is the object which we seek, and we require to know at what sacrifice of capability for carrying weight of cargo, in the case of mercantile ships, or of aggressive armament in the case of ships of war, that protection is to be obtained.

The drawing before us (Plate xxxii) represents the assumed midship section of a vessel proposed to be built on the raft principle of construction, and having a load displacement of say about 2,500 tons.

Now having predetermined that the length of our ship shall be six times the breadth, and the depth one-third the breadth, and that the lines of the vessel shall be such that the displacement expressed in cubic feet shall be one-half the product of the length, breadth, and depth, we know from these data that, to obtain a displacement of about 2,500 tons, the breadth must be about 45 feet, the length 270, and the depth 15 feet. These dimensions, under the above-mentioned conditions of construction, give the immersed hull a cubical content of 91,125 cubic feet, which, divided by 36, the number of cubic feet in a ton weight of fresh water, gives 2,531 as the displacement of our ship in tons weight, and consequently the total aggregate weight of our hull, buoyant packing, packing for surplus buoyancy, engines, coals, ship's stores, armour-plating, armament and ammunition, such being the entire weight of the ship and its burden, and we propose to treat of each of these items separately.

1st. *The Hull.*—For the sake of strength combined with lightness, we may suppose the shell and frame of the hull to be of steel, lined or planked inside with timber, and as the buoyant material with which the vessel is to be packed will greatly strengthen the shell of the vessel, we may assume the weight of the hull (including rig and equipment, but not including armour-plating, armament, ammunition, or other stores) to be 25 per cent. of the load displacement, amounting in this case to 633 tons weight.

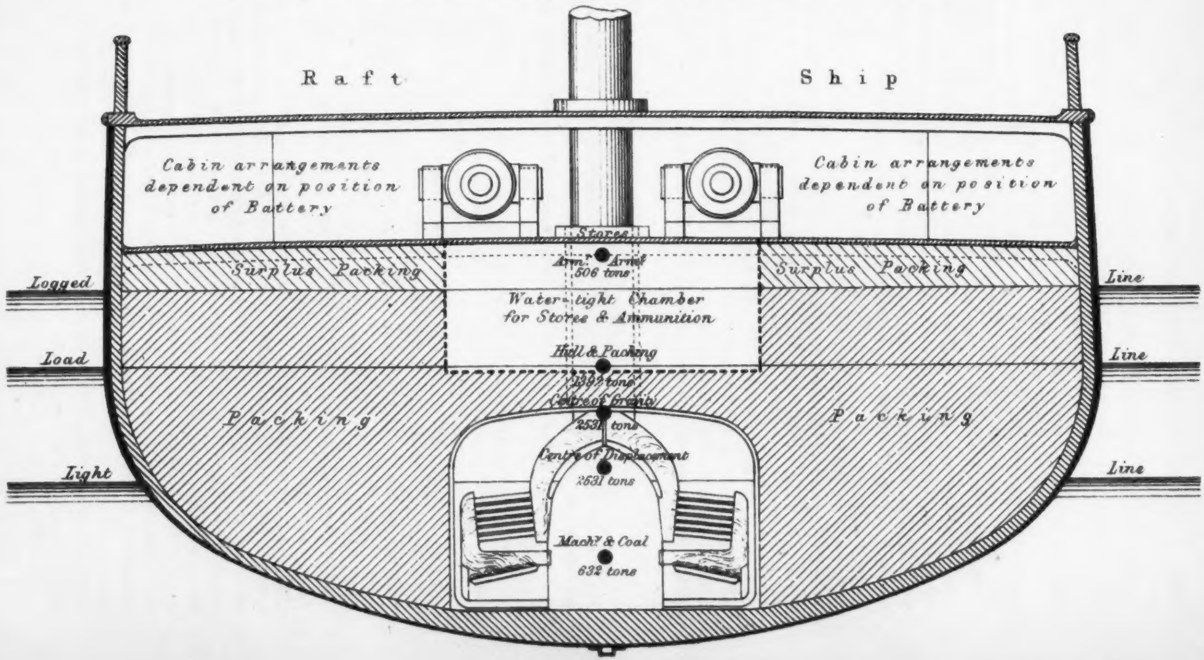
2nd. *The Bouyant Packing.*—This packing, on which the buoyancy of the ship is intended to depend, must be in such bulk, with reference to its specific gravity, that when floating in water, it will uphold from sinking the entire weight of the ship and its burden, consequently the bulk of the packing must be at least equal to the load displacement of the ship, being in this case 91,125 cubic feet, which quantity is represented as tinted pink on the drawing; and the specific gravity of this packing being one-fourth that of water, its weight will be one-fourth of the load displacement of the ship, or 633 tons weight.

3rd. *Surplus Buoyancy.*—We have hitherto made provision only for such quantity of buoyant packing as would merely float the ship, but in the case of ships of war, portions of this packing may be blown away by the explosion of shells, which may have lodged in the body of the mass; it is, therefore, proposed to allow 20 per cent. surplus buoyancy, coloured light pink on the drawing, amounting to 18,225 cubic feet, the weight of which is 126 tons, the same being 5 per cent. of the displacement.

The centre of gavity of the hull and packing, amounting to 1,392 tons weight, is shown on drawing.

4th. *Machinery.*—It is proposed that this vessel of 2,617 tons, builders'

Drawing to elucidate the principle of the proposed System.



J.R. Jobbins

measurement, or 2,531 tons displacement, be supplied with engines suitable for propelling the ship at the speed of about 12 knots per hour, requiring 316 horse-power, working up to 1,580 ind. horse-power; the weight of the machinery complete and in working condition will be 316 tons weight, being $12\frac{1}{2}$ per cent of the total displacement.

5th. *Coals.*—One ton of coals per Noml. H.P. will give about six days' supply, at full steaming power, amounting to 316 tons, being $12\frac{1}{2}$ per cent. of the total displacement, and as the weight of the machinery and coals is necessary to the stability of the ship, it is desirable that the coals be stowed in the lower hold, and that the coal-bunkers be fitted water-tight for the reception of water ballast; the centre of gravity of the machinery and coals, 632 tons, is shown on the drawing.

6th, 7th, and 8th. Stores—Armour-Plating—Armament and Ammunition.—Having already appropriated, as above shown, no less than 80 per cent. of the load displacement, we have now left only 20 per cent., amounting to 507 tons weight, to meet the requirements of ship's stores, armour-plating, armament and ammunition. The proportion in which these three items are to be distributed entirely depends on the intended armament for the ship, and the thickness of armour-plating which may be considered sufficient for the intended service. We may, however, assume the distribution as follows:—

Ship's stores 2 per cent., amounting to 51 tons.

Armour plating 12 per cent., amounting to 304 tons.

Armament and ammunition 6 per cent., 152 tons, of which the centre of gravity is shown on drawing, 507 tons. Hence the foregoing scale of appropriation of displacement gives as follows, viz.:—

Hull	25 per cent.,	weighing	633 tons.	1,392
Packing	25 „	„	633 „	
Surplus packing	5 „	„	126 „	
Machinery	$12\frac{1}{2}$ „	„	316 „	632
Coals	$12\frac{1}{2}$ „	„	316 „	
Ship's stores	2 „	„	51 „	507
Armour-plating	12 „	„	304 „	
Armament and ammunition	6 „	„	152 „	
	100	Dispt.	2531	

From the above scale of appropriation of displacement the following table has been deduced, showing the weights available for armour-plating, armament and ammunition, the vessels varying from 257 tons displacement, to ships of 10,368 tons displacement, the largest size now built, whence we may see approximately what amount of armour-plating is available for ships of different sizes, and thence determine whether such vessels will carry out the object we may have in view. The weights shown as armour-plating, armament and ammunition in the following table, constitute the tons weight of cargo which would be carried by the ship if fitted for merchant service.

No.	Dimensions. Length.	Dimensions. Breadth.	Dimensions. Draught.	Tonnage. O. M.	Cubical Contents.	Displacement.	Appropriation of Displacement. Hull, 25 per cent.	Packing, 25 per cent.	Surplus Packing 5 per cent.	Engines 12½ per cent.	Coals, 12½ per cent.	Stores, 2 per cent.	Armour, 12 per cent.	Armament and Ammunition 6 per cent.	Power. Nom.h.p.	Power. Ind.h.p.	Speed.
	Feet.	Feet	Feet	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.			Knots.
1	126	21	7	266	9,261	257	64	64	13	32	32	5	31	16	32	160	9·28
2	144	24	8	397	13,824	384	96	96	19	48	48	8	46	23	48	240	9·68
3	162	27	9	565	19,683	547	137	137	27	68	68	11	66	33	68	340	10·05
4	180	30	10	775	27,000	750	187	187	38	94	94	15	90	45	94	470	10·50
5	198	33	11	1,032	35,937	998	249	249	50	125	125	20	120	60	125	625	10·77
6	216	36	12	1,340	46,656	1,296	324	324	64	162	162	26	156	78	162	810	11·08
7	234	39	13	1,702	59,319	1,648	412	412	82	206	206	33	198	99	206	1,030	11·39
8	252	42	14	2,128	74,088	2,058	515	515	103	257	257	41	247	123	257	1,285	11·68
9	270	45	15	2,617	91,125	2,531	633	633	126	316	316	51	304	152	316	1,580	11·98
10	288	48	16	3,175	110,592	3,072	768	768	154	384	384	62	368	184	384	1,920	12·20
11	306	51	17	3,810	132,651	3,684	921	921	184	460	460	73	442	221	460	2,300	12·45
12	324	54	18	4,523	157,464	4,374	1,094	1,094	218	547	547	87	525	262	547	2,735	12·70
13	342	57	19	5,213	185,193	5,144	1,286	1,286	257	643	643	102	618	309	643	3,215	12·92
14	360	60	20	6,204	216,000	6,000	1,500	1,500	300	750	750	120	720	360	750	3,750	13·15
15	378	63	21	7,182	250,047	6,946	1,736	1,736	348	868	868	139	834	417	868	4,340	13·36
16	396	66	22	8,258	287,496	7,986	1,997	1,997	399	998	998	160	958	479	998	4,990	13·57
17	414	69	23	9,436	328,509	9,125	2,282	2,282	456	1,140	1,140	182	1,095	548	1,140	5,700	13·79
18	432	72	24	10,721	373,248	10,368	2,592	2,592	518	1,296	1,296	208	1,244	622	1,296	6,480	14·00

From the foregoing table we arrive at the following deductions:—

1st. With reference to armour-plating, it is manifest that in a ship of given size, as determined by displacement, the weight available for armour-plating is to a considerable extent a compromise with the weights required for machinery, coals and armament, as we increase the one we must reduce the other; but assuming the appropriations of displacement taken in the table, the rates allotted to armour-plating would give the following results:—

	Thickness, if plated all round, 12 feet deep.	Thickness, if plated all round, 16 feet deep.	Thickness, if plated all round, 20 feet deep.
No. 9	2·42 inches	1·82 inches	1·45 inches.
„ 10	2·75 „	2·06 „	1·65 „
„ 11	3·10 „	2·33 „	1·86 „
„ 12	3·50 „	2·62 „	2·09 „
„ 13	3·93 „	2·95 „	2·36 „
„ 14	4·31 „	3·23 „	2·58 „
„ 15	4·73 „	3·55 „	2·84 „
„ 16	5·21 „	3·91 „	3·13 „
„ 17	5·69 „	4·27 „	3·42 „
„ 18	6·20 „	4·65 „	3·72 „

It is also to be observed that if the length of the vessels be four times the breadth instead of six times the thickness of the armour-plating, in each case would be increased 50 per cent. on the above dimensions; and, moreover, if instead of plating the ships all round the armour-plating be confined to protecting the limited space of the battery, the thickness of the plating will be proportionately increased, the application of the weight available for armour-plating, armament, and ammunition is thus entirely a matter of arrangement dependant on the class of ship to be constructed.

It also appears that the ratio of power to displacement being given, and the vessels of similar type, the speed becomes greater as we increase the size of the ship. The extra cost that would be incurred in the construction of raft shipping may be approximately estimated as follows, supposing the material to be cork of the lowest quality, which is generally the lightest, and therefore the most suitable, for the purpose of raft ship packing. Take, for example, ship No. 9, of 2,531 tons' displacement:—

Cork for packing, 760 tons at £10	£7,600
Preparation for rendering the packing uninflammable, 760 tons at £2 10s.	1,900
Workmanship and labour, preparing material, cementing, and setting in place, 760 tons at £2 10s.	1,900
	£11,400
Casualties 5 per cent.	570
Total for ship of 2,531 tons displacement	£11,970

Being at the rate of about £5 per ton on the displacement tonnage of the ship.

Rear-Admiral E. P. HALSTED: Mr. Atherton has so clearly and completely given us all his details and definitions that the question is scarcely to be discussed, except upon its general principle. I find that the drawing before us presents a more solid structure of the floating material than I had anticipated. I had thought it would rather represent a filling in of the cellular spaces of which iron ships are now generally constituted; but from the paper just read, and from the drawing, it is clear that Mr. Atherton looks upon it as a question of absolute solidity. (Mr. ATHERTON: Yes.) This, of course, then becomes, with naval people, a question of accommodation, which does not seem to have been very comfortably provided for. However, there may be circumstances wherein vessels of that sort may be constructed for special purposes, perhaps with very great benefit; but the calculations, so far as one has heard them read, are based upon data which Mr. Atherton's own character is quite sufficient to show is correct. For general purposes, I think it will be a long time before we shall have such an unsinkable ship; but I can quite conceive there are special services in which vessels of that sort might be made available. I do not think Mr. Atherton has proposed any mode of getting over the inflammability of his material, because cork is very easily burnt, and anything like caoutchouc or india-rubber to bond it together so as to make a mass, will only add to its inflammability. However, I do not mean to say there are not means of making it practically uninflammable. I consider the proposal to be a very fair one to make to us in these days. Far greater changes have actually introduced themselves within the last ten or fifteen years even than the one which we have now put before us.

Mr. ALEXANDER GORDON: With regard to the question of inflammability, I am perfectly satisfied that Mr. Atherton is entirely correct upon that subject. I have had a great deal of experience in the preparation of timber for lighthouse and other works, where the danger of fire was considerable, and I found that by Mr. Maugham's process, which was patented many years ago, timber was rendered uninflammable. You may put a piece of wood so prepared into a furnace, and you may bring it out red hot, but it will not carry fire—it is uninflammable. I mention this after having had a great deal of experience with timber prepared by Maugham's process, and I regret that this process is not more generally known. In a conversation with Sir George Cockburn when he was at the Admiralty, I proposed the subject of so preparing the ceiling and internal fittings of H.M.S. "Simoom." It was also proposed to line that ship with kamptulicon so prepared, of which I produced some specimens perfectly uninflammable. Sir George Cockburn shortly after this left the Admiralty, and I am not aware that consideration of the subject has been renewed.

Captain JULIUS ROBERTS, Royal Marine Artillery: I do not think our worthy lecturer has given himself credit for points he might have taken up, showing very much better the character of that construction. At present he shows it in a very imperfect condition. There is in that embodiment vast strength. I know the lecturer has in his mind the idea of connecting the sides of the ship together by bulkheads, forming cellular compartments right through, which the drawing, being merely a cross section, does not show, so that each of these compartments, separately formed with thin sheet iron, make up very little addition to the weight of the cork. This would form a great protection against the penetration of shot, and those cellular spaces filled with packing would give the ship a vast amount of strength in every way. The question of mortars and vertical fire is that with which we shall have to deal one of these days. All our ships are utterly unprotected on the upper decks from penetration by vertical fire. A better study of mortars, a better study of vertical fire, and the greater precision of fire which may be obtained from that vertical fire, will render all our ships as at present constructed perfectly useless. That is a point our lecturer has touched upon to-night, and he feels it to be an important question, too. I have studied his plan before it was brought here. I have gone into it very carefully, and I quite conceive that the system might be very judiciously applied to our present line-of-battle ships, if not as an experiment, yet at no very great outlay, to solve a problem which is of paramount importance in the present day.

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Halsted is worthy of notice with reference to the accommodation. This, doubtless, has been considered by Mr. Atherton in his very interesting lecture, and he will be able to explain to us whether he has made proper allowance for the actual requirements of accommodation, besides the stores and coal, which are necessities in a vessel of war. We all know that in ships of the "Warrior" class, and vessels of those huge dimensions, there is a vast quantity of space left totally unoccupied, either by men or as accommodation for stores or coal. Perhaps Mr. Atherton may intend in such ships as these to apply that unused space for the packing. I did not understand from the lecturer the amount he proposes to put into a vessel. Perhaps he will be kind enough to explain how much of the present accommodation for men, officers, or stores, is to be dispensed with, for the purpose of filling with packing, if any.

Captain Selwyn, R.N.: I have long had the pleasure of Mr. Atherton's acquaintance, with very great benefit to myself in engineering matters; and I quite recognize the principle that seamen on shore should defer to the engineers in their element, as they wish the engineers to defer to them on matters with which seamen are familiar. I should now beg to put the objections I have rather on the form of questions than in any other way. First of all, I must venture to dissent entirely both from the lecturer and the gentleman who spoke just now on the subject of mortar fire. Vertical fire is not to be feared by ships as long as they have the power of locomotion. It is only when at anchor that vertical fire is to be feared; for it is utterly impossible for the most clever Officer so to proportion his charge, and so to change the elevation of the mortars during the interval between firing and loading, as to ensure his hitting the ship a mile off, or any distance beyond that with a vertical fire, which pre-supposes exact range, and the shell falling on a certain given spot, if that spot be suddenly changed, as a ship under steam is constantly changing, then it becomes utterly impossible to rely with any degree of certainty on mortar fire against ships. They are much more available from ships against forts, which are large fixed objects, than for forts against ships, which are small moveable objects. With regard to the rams and other powers, we must always recollect that the use of rams, and it is a question which has been rather neglected in naval architecture, is dependent entirely upon their possession of extreme speed, or superior speed, I may say, and the most perfect power of manœuvring. Unless these two conditions be attained, the use of rams is one which may possibly sometimes be brought into play against other vessels which are at anchor, but which can never be brought into play in those great naval actions which should take place, as they have always done, at least with the English, on the open ocean, where the question is how to chase your enemy, how to catch him, and when caught, how to dispose of him. The ram will play its part indubitably; but we must not rely any more exclusively on that than we must on guns, or on the peculiarities of ships, which may be attained, as Mr. Atherton has very properly remarked, by a compromise which sacrifices in a certain degree each one to all the others, that is to say, the speed may be attained by a certain sacrifice of capacity and of seaworthy qualities. The enormous power of carrying fuel may be attained by other sacrifices; and so we may go through the whole list of compromises, never being able to attain in absolute perfection the whole of the objects which we seek. With regard to penetration, and how it is to be resisted, Mr. Atherton, I think, does not intend that the cork or other buoyant material which he employs as packing should be viewed in any measure as a resistant material. He relies for that on the armour-plate outside, and which must remain very much as it is at present, a question between the power of the gun and the power of the armour-plate. If we build our ships of a lighter material, such as steel, we may then afford to devote increased thickness to the armour-plate, and, therefore, be able to resist heavier guns than those which are now brought against us. If, on the other hand, our enemies find that we are so disposing our weights, it is reasonable to expect that they will increase the size of their ordnance up to the power at which they may be effective against the increased resistance. The cheapest buoyant material we have, and that hitherto has been resorted to, is air—cellular spaces filled with air; and the only objection which I understand Mr. Atherton entertains to that, is the possibility of penetration in every line by

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Captain INGLEFIELD, R.N., F.R.S.: I think what has fallen from Admiral

Halsted is worthy of notice with reference to the accommodation. This, doubtless, has been considered by Mr. Atherton in his very interesting lecture, and he will be able to explain to us whether he has made proper allowance for the actual requirements of accommodation, besides the stores and coal, which are necessities in a vessel of war. We all know that in ships of the "Warrior" class, and vessels of those huge dimensions, there is a vast quantity of space left totally unoccupied, either by men or as accommodation for stores or coal. Perhaps Mr. Atherton may intend in such ships as these to apply that unused space for the packing. I did not understand from the lecturer the amount he proposes to put into a vessel. Perhaps he will be kind enough to explain how much of the present accommodation for men, officers, or stores, is to be dispensed with, for the purpose of filling with packing, if any.

Captain SELWYN, R.N.: I have long had the pleasure of Mr. Atherton's acquaintance, with very great benefit to myself in engineering matters; and I quite recognize the principle that seamen on shore should defer to the engineers in their element, as they wish the engineers to defer to them on matters with which seamen are familiar. I should now beg to put the objections I have rather on the form of questions than in any other way. First of all, I must venture to dissent entirely both from the lecturer and the gentleman who spoke just now on the subject of mortar fire. Vertical fire is not to be feared by ships as long as they have the power of locomotion. It is only when at anchor that vertical fire is to be feared; for it is utterly impossible for the most clever Officer so to proportion his charge, and so to change the elevation of the mortars during the interval between firing and loading, as to ensure his hitting the ship a mile off, or any distance beyond that with a vertical fire, which pre-supposes exact range, and the shell falling on a certain given spot, if that spot be suddenly changed, as a ship under steam is constantly changing, then it becomes utterly impossible to rely with any degree of certainty on mortar fire against ships. They are much more available from ships against forts, which are large fixed objects, than for forts against ships, which are small moveable objects. With regard to the rams and other powers, we must always recollect that the use of rams, and it is a question which has been rather neglected in naval architecture, is dependent entirely upon their possession of extreme speed, or superior speed, I may say, and the most perfect power of manœuvring. Unless these two conditions be attained, the use of rams is one which may possibly sometimes be brought into play against other vessels which are at anchor, but which can never be brought into play in those great naval actions which should take place, as they have always done, at least with the English, on the open ocean, where the question is how to chase your enemy, how to catch him, and when caught, how to dispose of him. The ram will play its part indubitably; but we must not rely any more exclusively on that than we must on guns, or on the peculiarities of ships, which may be attained, as Mr. Atherton has very properly remarked, by a compromise which sacrifices in a certain degree each one to all the others, that is to say, the speed may be attained by a certain sacrifice of capacity and of seaworthy qualities. The enormous power of carrying fuel may be attained by other sacrifices; and so we may go through the whole list of compromises, never being able to attain in absolute perfection the whole of the objects which we seek. With regard to penetration, and how it is to be resisted, Mr. Atherton, I think, does not intend that the cork or other buoyant material which he employs as packing should be viewed in any measure as a resistant material. He relies for that on the armour-plate outside, and which must remain very much as it is at present, a question between the power of the gun and the power of the armour-plate. If we build our ships of a lighter material, such as steel, we may then afford to devote increased thickness to the armour-plate, and, therefore, be able to resist heavier guns than those which are now brought against us. If, on the other hand, our enemies find that we are so disposing our weights, it is reasonable to expect that they will increase the size of their ordnance up to the power at which they may be effective against the increased resistance. The cheapest buoyant material we have, and that hitherto has been resorted to, is air—cellular spaces filled with air; and the only objection which I understand Mr. Atherton entertains to that, is the possibility of penetration in every line by

shot or by shell. Now, I think if we were to enter into a calculation of the thickness of the transverse partitions required to stop shot after they have penetrated a portion of the water (because they are not dangerous above the water line), but passing through a portion of the water, the armour-plate, and then a certain number of the cells, if that thickness of armour-plate and of armour-partition were calculated, we should find it rather inferior to the weight of the packing which would be required to prevent the ship becoming water-logged from these transverse perforations. There is another circumstance to which we may turn our attention usefully—that having engines on board, we can use them to pump air into the air-cells to keep out the water; and that, then, although perforated, the cells remain air-cells by the continued power exerted against the water. You can do that in this condition that the outer cells be kept free from water, and only if air be pumped into the interior ones can you keep out a head of water. It is possible to do that, and it is worthy of consideration how far we may do it in opposition to the system of filling up with a material which, after all, if perforated, does not keep out water. In proportion as the cells, whether the packing material be cork or light porous wood, are destroyed by the impact of shot, so will the water penetrate those cells and enter among the splinters or the powder into which the material would then be reduced, thus not giving us the full value which we should obtain, if we considered it only as cork having certain buoyant qualities. There is another remark which I might make, which is, that when by penetration in whatever direction, the ship has been reduced to what is shown in Mr. Atherton's very beautifully made diagram as the water-logged line, it is very clear, he says, that the engines might be drowned out, and the ship would certainly be drowned down to such a line of floatation that her manœuvring power would be gone, and then she would be at the mercy of any ship that ran against her having superior manœuvring power. I do not urge this as an objection, but I merely urge it as a remark as to what would be the result in such a case of water-log. When you have also a large quantity of buoyant material, if there be an alteration in the centre of gravity, you find, if you consider this ship as not alone carrying a hull, but carrying masts and yards, you will so seriously compromise the centre of gravity that you are liable to have your ship capsized, although she floats, particularly if she is in a sea. If it be possible, as Mr. Atherton seems to show, that we may have ships that won't sink, then it becomes a very grave question whether the cupolas may not be more efficiently introduced than they have hitherto been, for the whole secret of the want of success of the cupola system in large ships seems to be, that it is necessary to defend the ship as well as the gun. Not alone must you put armour round the cupola, but you must put iron round the ship, not solely to prevent her crew being hit, but to prevent her offensive powers being injured, and to prevent the ship being sunk. If it is possible to make a raft like that, we shall return to that ingenious invention, for which Captain Cowper Coles deserves the greatest credit, of putting heavy guns on an unsinkable raft. I hope by the devotion of such talent as that of Captain Coles as a Naval Officer, and as that of Mr. Atherton as an Engineer, to the subject, we shall yet arrive at a much more clear conclusion than we have hitherto been able to do.

Mr. Atherton: With respect to Captain Inglefield's remarks about the accommodation, this drawing has been prepared to elucidate the principle of the system under consideration, not to show the details of arrangements for the accommodation of the crew, and being a midship section it shows less accommodation than would be shown in longitudinal section, because the upper part, which in the diagram looks like solid packing, will be cellular. For instance, here is a cell which I have marked "stores and ammunition," meaning that the stores and ammunition will be stored in water-tight cells formed in the packing, so that in the case of the ship being sunk down to the water-logged line all the stores and ammunition will be accessible. The arrangements for the accommodation of the crew would be dependent on the number of the crew and position of the batteries. I do not pretend to know how a ship's batteries ought to be arranged, whether broadside, cupola, or fore and aft, but I have assumed that in this case the batteries would be fore and aft, thereby affording the usual amount of accommodation for the crew amidships between decks. The lower hold I mean to be exclusively appropriated to machinery and coals. The

coal will be put into watertight compartments, and as the coal is consumed the bunkers may, if necessary, be filled up with water, to preserve the stability of the ship. As regards Captain Selwyn's remarks (Captain Selwyn speaks of present mortar practice), I refer to the probable future. The mortar practice of the present system is not at all comparable to what I anticipate being resorted to as the agent for sinking iron clad ships, viz., masses of eight or ten tons weight being thrown nearly vertically to a considerable height, and falling into a ship through the deck at a range of say 200 yards only. As you shorten your range you arrive at greater precision, and doubtless mortar practice may be so modified that at short range, say 200 or 300 yards, you would not fail to drop a shot or shell through the deck of such a vessel as the "Warrior." With regard to the efficiency or otherwise of rams, it is not for me to discuss that question. I am of opinion they may become formidable rivals to ships of war as now constructed, and, therefore, I suggest this mode of rendering ships unsinkable, though assailed by the ram. With regard to penetration, the theory I go upon is that nothing will stop the penetration by shot. I anticipate that the penetration will be absolute, but whilst the packing remains an integral part of the ship it will float the ship. You must entirely get rid overboard of that 127 tons of surplus packing before this ship of 2,531 tons displacement will sink. As regards air-tight cells, if of iron, they would probably be of equal weight, and occupy the same space as the packing. I believe it would be very difficult to make the cellular system absolutely air-tight, and if perforated by shot they would become non-effective. By the proposed system when the vessel becomes perforated and waterlogged, we still have the lower deck some two or three feet above the water-logged line of flotation; therefore, I do not see why that ship, though waterlogged, should not be perfectly manageable and seaworthy. Many a ship goes to sea with a water line as low as that. As regards stability, this ship would be much more stable if that were the water line (pointing to the water-logged line on the diagram) than she would be if that, the lead line, were the water line. The stability increases as she gets down, because the centre of gravity becomes lower with reference to the centre of displacement.

The Chairman: I am very glad Captain Inglefield has put the question he did, because it is a thing that must naturally occur to any of us, as to where the stores and coals are to be put, if, according to the drawing, the whole of the lower part of the ship is to be filled with packing. However, Mr. Atherton seems to have provided in some degree for that, although he seems to have devoted his attention especially to the displacement, that is to the weight of water the cork he will put in will displace, and not to the space that the cork itself will occupy. It seems to me he puts so large a quantity of the cork into his ship—759 tons—that he will find great difficulty in carrying the six days of coal which he proposes to carry. Then there was another remark that Mr. Atherton made—that the packing would increase the strength of his ship. I do not pretend to be a ship-builder, but I do not understand how by putting cork into a ship you can make it conducive to the strength of the steel skin which forms the outside of the ship. However, I dare say Mr. Atherton has some ingenious way of increasing the strength of the vessel. I think I may now call upon the meeting to return our thanks to Mr. Atherton for his very interesting paper.

CLARKSON'S PATENT CORK MATERIAL, AND ITS APPLICABILITY TO MILITARY AND NAVAL PURPOSES.

By Mr. Thos. Chas. Clarkson.

I feel it a great honour in being allowed this opportunity of bringing the subject of my Patent Cork material, before the Council and members of this highly practical and scientific Institution. I think it would be a waste of time to go into a statement of the growth and particulars of obtaining and preparing Cork from the forest, and of the different qualities of Cork, as I make nearly all descriptions of Cork answer my purpose; it will also be unnecessary to go into particulars of the preparation of the hide, for this I shall have to refer to shortly, nor is it necessary to dwell upon the production of cotton, flax, or caoutchouc, although they are important items in my invention, and on the latter depends the union of my materials. The above named articles are familiar to most persons to a greater or less extent.

Having a great many objects before the meeting made of my Patent Cork material, all of which have been subjected to more or less practical tests, it will be preferable first to show what this material is, and how composed, and then how it can not only be applied to advantage to military and naval purposes, but also for the use of the human family generally.

First, my Patent Cork material gives the required amount of elasticity under any amount of pressure or friction, and an absorbing medium of concussion without subjecting itself to injury, or causing injury to any substance with which it may be united or embodied; it compresses without any lateral spreading or disturbance; and if subjected to remain under pressure, it never shrinks from the bodies that hold it under compression, or receives injury from such pressure; if quickly released, it does not cause any injurious or quick recoil; the very opposite to that caused by India-rubber. When India-rubber is submittted to violent concussion, it is subject either itself to burst, or to burst the caseing that holds it; and under compression, as the pressure increases, so the rubber spreads laterally, preparing itself, if I may be allowed to use the expression, for violent reaction, which, when used in connection with railways, or in gunnery, causes injurious results, too well known to require comment. The Cork material is composed of alternate layers of woven fabrics, such as *canvas*, or *webs of flax*, prepared hides, with layers of sheet Cork, varying in thickness according to the articles to be made; wood and iron are mixed in when the articles are required to be more or less rigid. If rigidity be required, more layers of wood and less of Cork are used; if more elasticity be wanted, more layers of Cork than of wood are employed. If a greater toughness be desirable, more layers of canvas or other woven fabrics, or prepared hides with thinner layers of

sheet Cork, from one-sixteenth to one-eighth of an inch in thickness, are introduced; if the material is not to be subjected to violent concussion, but merely to act as an absorbing and an elastic medium with the force thrown over a large surface, the Cork, wood, and canvas are arranged accordingly, giving more or less of one or other of these materials, in alternate layers, as the case may require. By such means *vessels, boats, carriage bodies, powder cases, pontoons, military waggons, gun beds, platforms, buoys, beacons, saddles, harness, boots and shoes, shakoes,* &c., may be constructed, all of which, when properly made, are one-third to three-fourths lighter and stronger than the ordinary articles of a similar kind in general use.

I propose dividing my subject into three parts.

1stly.—To show the quick and simple method of producing my Patent Cork material from the raw materials, and why this invention demands not only individual but national notice now that free trade is becoming adopted by all nations.

2ndly.—To show how the articles are made, and that they offer unlimited employment for women and young people.

3rdly.—The advantages which the patent articles possess over similar ordinary articles now in general use.

With regard to the first point, here is a sheet of Cork as imported into this country; you will perceive it is rugged, and not very sightly, and you would scarcely suppose that such could be efficiently applied as the foundation for the variety of uses before named. You see how apparently rotten and tender a substance Cork is, and that it is easily broken and pulverized, but the sheet I hold in my hand is as thin as a Bank Note. This is an article used for lining hats, and the hats so lined are called Cork hats. I would advise the gentlemen present and the public not to be imposed upon, but test such hats when buying them, by giving them a squeeze; if they will not stand trial they are not genuine Cork hats, and not made of Clarkson's Cork material. This sheet of Cork is one-sixteenth—this is one-eighth of an inch thickness. The Cork in this state is, as you perceive, a very brittle article, until made to adhere to a woven fabric similar to this piece of canvas. You perceive, I can bend the Cork in the direction of the side to which the canvas is adhered, but if I bend it the other way it breaks. When a second piece of canvas is adhered on the other side, you perceive that the Cork cannot by any possibility be broken; double it, hammer it, do what you like, you cannot break it. I have only to repeat the layers to attain any thickness I require, so as to act under any force that can be applied to it. If I require a cylinder, or a case, or any peculiar configuration, I resort to a mould, and proceed in the manner just shown.

Here is a military saddle made without a wooden tree, without stuffing, sewing, or nailing; it is as if it had grown; it has the advantage of not being liable to be broken or put out of shape, it cannot get heavier as it cannot absorb wet, damp, or sweat from the horse; it can be made larger, in a moment, by merely cutting away the part required, or smaller, by sticking a piece on. This may appear rather paradoxical, but it is true. In this principle of making saddles, no steel springs or

wooden trees so apt to rot or corrode are required, whilst these Patent Cork saddles are more than one-third lighter than the ordinary saddles. It will be found that these saddles yield when the horse jumps, instead of being rigid, they, to a certain extent, act in concert with the spring of the back bone of the horse, so beautifully formed by nature for the active motion of the animal. This is a strongly made specimen of my Cork material to be used in lieu of thick leather, so extensively employed in the service. I do not call it imitation leather, for it is the real thing although different to ordinary leather. It has, as you perceive, a leather surface, and has a pliant and soft feel such as cannot be produced in leather, and it is not subject, as leather is, to become affected by wet or damp, and it cannot be put out of shape; it is lighter and cheaper than leather, and can be produced from the raw materials, I have just shown, in from ten to fourteen days. In fact, my prepared leather can be produced from the hide of the animal in less than the above-named time. This I now show is an important production; it is what is termed a housing, and is used for heavy cart and military harness; it has many advantages over thick leather; it is cheaper and not so heavy, and it does not require an iron frame to keep it in shape, as is the case with ordinary leather.

These are artillery-traces. One of the great advantages of my Patent Cork material for traces, straps and harness is this, that the wet cannot penetrate the straps, consequently the fine strong flax web, which is in the interior, and is attached to a thin layer of sheet cork, cannot become injured, rotten, or hard. The external leather cover preserves the web from damp and chafing. The whole of the bodies, being thoroughly made to adhere to one another by water, heat, and sweat proof cement, require no sewing or rivetting. I am frequently asked what good can Cork do in such cases. I answer in the first place, when tension is put on the strap, it keeps the strap firm, and prevents it from buckling, as it would otherwise do if there was merely the web; and in the next place it keeps the web from cutting, and the strap soft, and the internal part of the strap is not liable to get hard, the wet never passing deeper than the external leather cover. The leather, under such circumstances, cannot become brittle or hard, consequently it is not so liable to break. As is well known, in military harness the leather which envelopes the rope traces, does not adhere closely to the rope, and if once wet, the loose leather cover prevents the rope or web from getting dry. The result is that the rope mildews, and often in cases of emergency, the rope and web break: this cannot be the case with my traces.

The trace before you is one of my light traces made of the Cork material, covered as you see with leather. It was tested at the Royal Arsenal, Woolwich. It is $1\frac{1}{2}$ inches wide, $\frac{1}{4}$ inch thick. At a strain of 1232 lbs. the iron hook broke; the hook was the Government regulation hook; the strap was then sewn to form a loop, the sewing gave way at a strain of 1804 lbs.; the strap was then resewn, and it did not break until 2838 lbs. were hung on to it. The fracture is now repaired, and the strap is as good as the first day it was made, as you may perceive. This process will not only save the service great expense, but give lighter and stronger harness, and whatever the strength is at first, it may be relied upon to keep sound for twenty years or more.

I now come to another important branch of manufacture, and one interesting to the military and naval services. The shoe which I hold in my hand is also made of the Patent Cork material without seam, sewing, or nailing. It is one-half to one-third lighter than an ordinary leather shoe. This shoe cannot gall the feet, and is made, I believe, on sound principles. The upper part, which requires a little firmness, has alternate layers of thin Cork attached to an internal cloth or canvas lining, and then covered with an external leather cover. The sole is made to adhere to a layer of sheet Cork, consequently, in walking, as the feet come in contact with the ground, the concussion is relieved by the yielding of the Cork. These shoes can be made waterproof or ventilating, thus doing away with goloshes, which subject the body to unnecessary exertion, and the feet to unequal pressure. Now, were a soldier's shoes made of the Patent Cork material, it would not only reduce the cost to 1s. 6d. or 2s. per pair, but would remove the excess of weight which exists in the clumsy and heavy shoes now worn in the service by one pound per pair; this is, therefore, so much dead and unnecessary weight to be lifted, and which amounts in a march of 14 miles, to the enormous weight of 28,000 lbs., or about 13 tons. This is a good deal to take out of a man in one day's march. I do not, however, stop here; I take another 2 lbs. off the man by my cork shako, knapsack, and other accoutrements, making 3 lbs. per man. I thus relieve him of between 30 and 40 tons of weight equal to so much wear and tear of his body in every 14 miles march. I should like to have the problem solved as to how much wear and tear it takes out of a man in the time of his service in the army. In ten years, I make it to be somewhere about 130,040 tons in the carriage of superfluous weight; how many tons of bread, beef, and beer, &c., must be consumed by him to make up for this excess of wear and tear? Having said so much of the advantage of my shoe to the soldier, allow me to say a word about its advantage to the sailor. Here is one of my Cork shoes, a sailor's shoe, and here is one of the ordinary service shoes; this is an important matter to Jack, because all nautical men well know that if Jack had his own will, he would never put on a leather shoe. It is to him like putting a clog to a horse, and well it may be; what with the thick, clumsy make and stuffing between the sole and insole, when once wet with salt water, it never again gets dry. If he should by chance fall overboard, he might as well have a lead weight hung at his heels; now, the Cork shoe can be covered with canvas instead of leather; if a man falls overboard he feels no weight to his feet, and can swim as well with the shoe on as without it. I think Jack would never be found minus his shoes if made of Cork. They are only half the weight, and if wet they soon become dry. Having said so much about a covering for the feet, permit me to say a few words about a covering for the head, not only applicable for the troops, but for others. This is a shako made of my Cork material; it has been worn in the British army for four years; it illustrates what a tough and non-destructible article the Cork shako is. In 1857 the Government were anxious to remove from the heads of the troops the hard felt shako at that time worn. My Cork head dress was submitted to His

late Royal Highness the Prince Consort, and also to His Royal Highness the Duke of Cambridge, in competition with others, and the Cork was approved. Now, it was never known for the head dresses of the infantry at a cost of 6s. 6d. to last beyond two years, thus making the cost 3s. 3d. per head, per annum. The Cork shakos, at the expiration of two years, were found in such good condition that they were ordered to be continued in wear, and were worn two years longer, making a total of four years; the Cork body at the expiration of the four years was perfectly sound, and only required new leather bands; the shako would then be wearable for another two years. By the introduction of my Patent Cork head dresses for the use of the infantry, I have reduced the cost of each from 3s. 3d. to 1s. 2d. per annum. These shakos have been worn four years in the 55th regiment. You perceive that the cloth looks quite fresh, thus showing that when bodies are thoroughly adhered, particularly on an elastic medium like Cork, that friction and wear and tear are much reduced. This improved Cork shako is made without sewing or seam; it is more comfortable to wear and is perfectly water tight, as the rain cannot pass down between the peak and the body. The metal socket is replaced by a leathern socket, thus removing that liability to injury to the head of the soldier, which exists in the ordinary shako; all the reports from the various regiments that have worn the Cork shako, without exception, from the commanding officer to the privates, speak in the highest terms of it. It has not only been the means of removing from the heads of the troops a hard, heavy, uncomfortable head dress, but it has been the means of saving the country five thousand pounds per annum.

I now beg to exhibit to the meeting a cylindrical case applicable for storing gunpowder, and also for preserving any description of articles from damp or wet. This case, which only weighs 9½ lbs., has been submitted to a very severe test, viz., it was filled with 100 lbs. of sand, and dropped from a height of 18 feet upon a hard pavement, and, as you can see, it is not in the least injured. The barrel which is now in use in the service for storing and conveying gunpowder, weighs 32 lbs., when well coopered. It was filled with 100 lbs. of sand, and dropped from the same height on a hard pavement. The result, as you see, is, that the head was splintered and the barrel burst, and let out its contents. Had the barrel been filled with gunpowder, an explosion would probably have occurred.

Here is another description of powder case having an internal lining of copper, and cased with wood; it weighs 49 lbs. This was also subjected to an 18 feet fall, filled with 100 lbs. of sand, the wooden case is smashed, and the copper case is buckled.

A Cork case of the same size, weighing 15 lbs. was submitted to the same trial, and there is not the least fracture or mark so as to denote that it had ever been tested. A saving of 34 lbs. dead and unnecessary weight is thus gained, independent of greater security against explosion and sacrifice of human life; looking at the excess of weight in one case, it may not strike the mind, at first sight, but if we take 1,000 cases the excess of weight beween the service case and the Cork case, is some-

thing enormous, viz., 34,000 lbs. As to the result of what an iron case offers, you here see the chime knocked in and the bottom split.

The Cork material has, I think, great advantages for the making of limber boxes; the Cork limber box not only weighs 46 lbs. lighter than the service limber box, but the shells are preserved from that injury by lateral and vertical shaking, which in the ordinary service limber, the jolting of the carriage when passing over rough ground causes.

The Cork frame, with round holes placed round the inside of the box and into which the shells fit, so holds them that the lead coating cannot get damaged and the powder with which they are filled is prevented from being shaken to dust, as is the case when the shells jolt about as they do in the service limber box.

I now come to another article for military service to which the Cork material is adapted, viz., pontoons. This is a rough model of a pontoon boat, which can be arranged to perform many purposes either as a part of a bridge, as a sailing or rowing boat, as a gunboat, or as a fire-ship. It can be submerged and at pleasure made to rise to the surface; if it is hit with shot, or however damaged, it cannot sink as one made of iron, wood, or any other material, would do.

This piece of Cork material composed of eight layers $\frac{3}{16}$ of an inch thick, with eight layers of canvas, has been under 30 tons pressure; it has been fired at and hit with Minié balls, three of which have passed through it in the space of three inches and the holes have closed; with all that no damage has been done to the material, and there are no splinters. The same bullets passed through a piece of wood giving off several splinters. By way of giving some idea of the strength and toughness of this material, in the year 1851, the Lords of the Admiralty ordered it to be tested at the Royal Dockyard Woolwich, also my boat, under the superintendence of the Master Shipwright, O. Lang, Esq.; Captain McDonald, Master Attendant; and C. Atherton, Esq., Engineer-in-Chief. The test was as follows: a piece of the material 9 inches wide, 6 inches thick, composed of four layers of wood of half-an-inch thick, with alternative layers of sheet Cork one-eighth thick and canvas, made to adhere by means of water-heat and damp-proof cement, was placed under the steam hammer and received a blow at a foot stroke which caused no injury; a second blow was given and still no injury; it was then suggested to give it the full force of the large steam hammer; most extraordinary to say the block of material did not give way until the third blow was given. All descriptions of wood of the same size were submitted for test, and at the first blow, at a foot stroke, every piece broke into splinters. My Patent Cork material was then subjected to a pressure of 40 tons in the hydraulic press; the material compressed to one-half its original thickness but did not spread laterally, and the layers of Cork resumed their original thickness, but the layers of wood compressed one-third and remained so fixed, and the fibre was destroyed. A shot was fired into the material, and it did not splinter, and the hole closed, but the wood splintered considerably. See "Admiralty Report, Feb. 1852."

Another application of my Cork material is that for building boats which cannot be broken, stove in, or submerged. My boat exhibited at Portsmouth could not be submerged under the test that would have sunk all the boats carried by a line-of-battle ship of this or any other country. This is a model of a boat I built; I was the designer and also builder, being compelled to become so, as all the boat-builders set their faces against the use of my Patent Cork material. The boat, however, on trial, proved not to have an equal in *any* point, as a sea boat, in pulling and sailing. In a gale of wind, at Spithead, in racing the pinnace of H.M.S. Colossus, pulled by 16 men of that ship, my boat, pulled by 8 old men taken from the rigging loft at Portsmouth Dockyard, who had never before been in it, beat the pinnace in a heavy gale and against a strong tide. In sailing I again beat her, and weathered the ship; the pinnace had to be towed up.

To prove that my boat could not be broken or sunk by ordinary means, I had her launched from the dock wall, a height of 18 feet from the water, with ten of the crew of the Queen's yacht and myself on board, in the presence of the King of Sardinia, His Royal Highness the Prince Consort, the Duke of Cambridge, and suites, and with the greatest success. At the regatta at Sunderland, she won the Ladies' Prize for lifeboats open to all the world. She is reported to be the best boat on that station; she is now stationed at Sunderland, and was presented to the Sailors' Union by Miss Burdett Coutts. I travelled with this boat by sea and rail over 4,000 miles to test all the different lifeboats, but could not induce the National Lifeboat Institution to allow a trial with their boats. Here is a specimen of a piece of material for forming air cases for lifeboats. When a case is made for lifeboats to cause displacement, of course any injurious force must naturally be given from the outside, consequently the canvas which prevents fracture ought to be placed on the inside of the case, opposite to the direction of the force, and not externally only, as is applied to the present lifeboats. I strike the outside, as you see, and it fractures the wood; I now reverse the order, and I cannot fracture the wood, consequently you get a more powerful case without any extra weight. Nature proves it. Take the shell of an egg, for instance; the membrane lining it is on the interior and not on the exterior; the canvas acts similarly in my case.

This life-buoy made by me swims with 52 lbs. of iron; Curt's buoy submerges with 33 lbs. My buoy will sustain three persons at the same time, 10 lbs. weight in the compartment of valuable property, and three quarts of fluid, wine, or spirits, by first passing a bladder through this opening and then filling it; the screw in the neck secures it, and the liquid can be sucked out when the men are overboard, in a case of emergency.

The various articles I have had the honour of submitting this evening must not be looked upon as having attained perfection in finish or in handicraft; they are mere attempts practically to demonstrate that my Cork material is not altogether a *myth*. It does not at all follow that a patentee can always manipulate and perfect articles at the outset;

although his ideas may be clear upon the subject, it naturally requires experience for him to become thoroughly practical, and he should have the aid of the men who have been brought up to making similar articles in ordinary use. How often it happens that a patentee meets with the strongest opposition from those wedded to the old principles and with strong prejudices. Therefore, as I before said, you must not look upon the articles before you—although some of them have withstood such extraordinary tests—as of the highest finish or completeness. I have myself been compelled to become a practical man in all the said branches, independent of the trade I was brought up to, viz., that of a tanner and currier, but seeing in these two branches of manufacture such fearful waste and the opposition of the workmen to any improvements, I was induced to act independently of them. The result has been the taking out of a patent for the combination of Cork with leather, cloth, or other textile fabric for the many useful purposes to which you here see it applied. My first step was a most unfortunate one for me, as I was induced to attempt to build a lifeboat; and here again I was compelled, not only to become a practical boat-builder, but a designer; but here my success proved a misfortune, as it raised up a spirit of ill-feeling in those whose duty and whose humanity ought to have taught them to have acted more liberally, particularly in a cause where the saving of life from shipwreck was concerned. The articles I have here exhibited, however, fully bear out the applicability of my material for the various purposes I have named.

In conclusion, Sir, I beg to thank the audience for their kind attention, and shall be glad to give any explanation relative to the articles before them, or to hear of any to which the material may appear applicable, for there are many other important applications that I have not named, as, for instance, elastic backing for iron plates, for lining iron vessels, and cushions for the rail on railways and railway bridges, as beds for guns to absorb concussion; but these can be better understood in the workshop, in the presence of the steam hammer and hydraulic press, where the peculiar properties of my material may be ascertained and tested.

Mr. Clarkson stated that he had suggested to the Admiralty the application of his material for the lining of ships: not an application of thick cork, but merely put on according to his principle, in a thin layer, and he contended that the bottom of a ship covered with prepared leather and cork, would wear out copper or any other material of that description.

The Chairman: Do you propose to put the cork on the outside?

Mr. Clarkson: Yes; but the other day I went down to the "Bellerophon" to put my Cork material on the *interior* of the vessel: the next morning I found that where the cork had been attached, the iron on the inside was perfectly dry, though the damp was running down the iron in other parts of the vessel. Again, the side of the vessel exposed to the heat of the sun, where the cork had not been attached, was quite hot, but where the cork was, it was perfectly cool. As the cork was applied closely to the iron skin of the vessel, no space was lost, and the foul air which you have when any other kind of lining is used, and which you cannot get rid of, is avoided. The Cork material could be applied plain or ornamented, and at any price you like.

The Chairman: How is it fixed?

Mr. Clarkson: It is fixed with water and heat proof cement in a moment.

I had intended to have shown some experiments, but I have not had time to do so.

Captain SELWYN, R.N.: The point which particularly interests us, naval men, exclusive of the powder cases and boots, which might keep our feet from getting wet occasionally and our powder dry, is, I think, the point of coating ship's bottoms. It may be useful to Mr. Clarkson, if I simply state a fact which all the providers of materials for coating ship's bottoms will persist in ignoring—that in proportion as the material of the ship's bottoms exfoliates, so it is kept free from marine vegetation. It is not in proportion to its protection from such loss. If that were the case we should put the wood alone.

Mr. CLARKSON: You cannot stick the wood to the iron.

Captain SELWYN: The more indestructible your compound, the worse it is for our purpose. We put copper there because it oxydises rapidly in salt water, and thereby never leaves a surface on which any vegetation or any marine animalculæ can attach themselves. Copper is the most destructible metal in salt water; and that is the reason why we put it there. And if you devise anything that is indestructible, you will have wasted your time and gone in the wrong direction.

Mr. CLARKSON: The reason why I fix my material to the bottom of ships is because it is indestructible. You cannot closely attach wood to iron. If I can stick my cork upon a body, I completely prevent the destruction of the body that it adheres to. The gentleman was speaking of the decay of metals. In this specimen you see that the metal is gone, but the material to which it adhered is not gone, —this has been exposed ten years to the weather. If you can preserve the iron from decay, there will not be decomposition. You cannot preserve it by any means adopted yet.

Captain SELWYN: Are you speaking of the inside or the outside?

Mr. CLARKSON: I am speaking of both the inside and outside. If you put wood to iron, it cannot adhere closely, because you have air getting in between, and you cannot keep the salt water from the iron.

The CHAIRMAN: I am sure we are much obliged to, and thank you, Mr. Clarkson, for showing us such a number of ingenious applications of your Cork material; but I do not think you took up the point which Captain Selwyn wished to impress upon us, viz., that because copper, oxidizes, therefore animalculæ do not adhere to it. What he means is, that if your material does not decay, the animalculæ would adhere, and would produce the very evil which we wish to avoid.

Captain SELWYN: Precisely.

LECTURE.

Friday, June 9th, 1865.

General The Right Hon. the LORD HOTHAM, M.P., President of the Institution, in the Chair.

"THE RIGHTS AND DUTIES OF NEUTRALS IN TIME OF WAR." Part I.

By W. VERNON HARCOURT, Esq.

MR. VERNON HARCOURT,—Gentlemen, I must commence by apologising to the Institution for the very imperfect form in which I shall be able to offer the observations that I have to address to you. In the press of business I have not been able to write the lecture: therefore I must ask your indulgence while I offer what might more properly be called a few remarks upon the important subject which I have proposed to discuss, rather than dignified by the solemn and important title of lecture.

The subject is an extremely large one, and one of very great importance. Of course, in the space in which I can hope to occupy your attention, I shall be able to touch it extremely briefly, and only allude to some of the leading and principal topics.

First of all, the whole subject matter in discussion depends upon that which is, somewhat inaccurately perhaps, called International Law. Now, in the word law we assume and suppose the existence of some superior authority, which lays down rules and has the means of enforcing them. As between nations, I need hardly say there exists no such superior authority; and except as occasionally happens by a combination of nations, there is no means of enforcing those laws, even if there were anybody who were entitled to lay them down. I think, perhaps, the more accurate term would have been, if it had been originally adopted, to have called it International Morality. For, after all, what we mean by International Law is that which, more or less, by the consent of civilised nations, is admitted to be that which one nation ought to do in its relations to another. That has not been established, as laws are established in civilised communities, by the sanction of a legislature, or an autocrat, or whatever may be the power that has

the right and duty to impose laws. The duties which we understand by International Law are those which, as I have said, are considered obligatory from time to time in civilised societies according to a standard varying, and we hope progressing, with the morality of the time to which those rules were applied. You may say that in ancient times there was no such thing as International Law, because the conception that existed among communities was that nations owed no duty and no obligation to one another. We know that in the Roman times they used the same word for "a stranger" and for "an enemy;" *hostis* meant "a stranger," *hostis* meant "an enemy." They had no conception of communities of men, living in different countries and under different governments, owing any obligations to one another. Indeed, it seems to have been a very long time before such a conception developed itself. As you know, the greatest atrocities were committed in ancient times. In Thucydides, a sentiment which to us would seem abominable, is propounded there almost without condemnation, viz., that to king or commonwealth nothing is unjust that is useful.

It can hardly be said, even in the early days of Christianity, down, I might almost say, to the seventeenth century, that there existed among the communities of Europe anything which could be called even an International Morality. Grotius may almost be called the discoverer of that great truth. It was a discovery that was forced upon his mind by the abominable cruelties and crimes which arose in the great War called the War of Religion in Germany—called the War of Religion, I suppose, in connection with that line which we all know in Lucretius:—

Tantum religio potuit suadere malorum.

Indeed, Grotius, in the beginning of his great work, states his reason for writing it. He says—"I see throughout the Christian world a licence of warring at which even barbarians might blush: wars commenced on trifling pretexts, or none at all, and prosecuted without reverence for any law human or divine, as if that one declaration of war let loose every crime." It was the sight of what had taken place in Germany that led to the composition of the great book from which, in point of fact, we may say the gospel of International Law commenced. Since that period, of course, there have been great changes in the history of International Morality. Various opinions have prevailed at various times, according as the interests of belligerents and neutrals prevailed. We have seen on the one hand a code of belligerent warfare made more severe: on the other hand, attempts, sometimes successful, sometimes unsuccessful, to enlarge the rights of neutrals.

Now, gentlemen, it would be quite impossible for me to attempt here to investigate one of the most difficult, perhaps, and complicated of all questions, viz., a definition of the true bases upon which the principles of International Law repose? Various methods have been adopted by different writers in investigating questions of that description. Some have preferred to base it upon general principles, and to argue from those general principles to the practice which

they desire to establish. The very eminent modern French writer, M. Hautefeuille, has adopted that method. It seems to me that that method is not altogether successful; first of all, because people frequently do not agree upon the general principle; secondly, because it is extremely difficult to reconcile the consequences to those principles after you have adopted them. I think, on the whole, the reverse method is far the more convenient, *i.e.*, to take the historical method; and then you see, practically, how it is that the practice, recognised as that which is lawful and right among nations, has grown out of the progressive experience of nations; and instead of what we may call the deductive method, which M. Hautefeuille has adopted, to adopt what has certainly been the more common method in England—the historical method, and examine from time to time the practice of nations—that practice accommodating itself to the necessities of the times and to the civilisation of the age, and varying, of course, with the conditions which compose it.

Without pursuing that interesting discussion any further, I would say that the basis of International Law or International Morality is founded upon the customs of nations, governed, no doubt, to a great degree by the reason and conscience of mankind at the time to which it is applied. Having given that general definition of it, I would only now state the sources in which it is generally to be found. You find the practice of nations declared in the page of history, in the first place. You find it next in the text-books of writers on polity, like Grotius and others. You find it more or less recorded in treaties, though on that subject I would make one remark, and give a caution which is necessary to be observed. Many writers, especially continental writers, have chosen to classify as a separate head what they call the conventional law of nations; they appear to suppose that because certain nations have agreed—two or three nations, or four or five nations—that certain things shall be done as between themselves, that by making such a convention as this, the law of nations is altered. That seems to me an entire mistake. In point of fact the agreement shows that the law itself is something different from the agreement before it was made; consequently that treaties, unless they have been universal and continuous in operation, shew rather what are the exceptions than what are the rules of the law of nations. However, treaties and a continuous course of treaties, for a long period of time, no doubt form an element which is to be considered in discussions on International Law. Above all, there is one more important and valuable source than any other, that is, the decisions of prize courts. It is singular enough that almost all the continental writers too much disregard that source of authority, partly because I believe the decisions of prize courts, certainly the most valuable ones, are to be found in England and America, and consequently are enshrined in a language which is not accessible to many of those writers. I believe that to be one of the reasons why that source of International Law has been so much disregarded.

Now, I must waste no more time upon preliminary observations if I am to come to the points which we have proposed for our discussion. The question is that of the rights and duties of neutrals in time of

war. In order that there may be a neutral, it is necessary that there should be a belligerent. It would seem to be one of the simplest things in the world at first sight to determine what are belligerents But, apparently, from the present state of opinion, at least in America, that is not an easy subject at all; on the contrary, a very difficult subject. For we find that persons are making complaints against this country for having acknowledged the existence of a state of war and of belligerency, which they say never existed, and to acknowledge which, they affirm, was a wrong on our part. First of all, as between established governments, there can be no doubt whatever that war exists by the very fact of the parties warring upon one another, either with a declaration of war or without a declaration of war. In such a case there is very little difficulty in arriving at a conclusion on the subject.

Then, there arises another state of things which is different from that of war between two States, and that is the condition of insurrection by a part of one State against that which was originally its lawful government. Now the existing sovereign government is extremely unwilling, until the very last moment, to admit the existence of war as apart from insurrection on the side of its former subjects. How is that to be determined? First of all, it is clearly a question of degree and a question of amount. It would have been absurd to call Smith O'Brien's battle in the cabbage garden a legitimate war. On the other hand, it seems to me it would have been equally absurd to have refused to treat the millions of people who formed themselves into the Confederate States of America as anything else than a body of men in a condition of legitimate war.

Now this is a question upon which, fortunately, there may be found a very great amount of authority. In former days, of course, when the views of government were much higher than they are now, when it was considered impossible to conceive of the existence of any authority except that which was deposited in the old organisations that have been recognised from ancient time, when an insurrection first presented itself, it presented itself in a very different form from that in which it does in the present day; nevertheless, during the insurrection of the Low Countries against Spain, and at a later period, the insurrection of the North American colonies against England, these questions were ventilated, and were practically settled by precedents which leave very little room for discussion; and at a still later period, in the case of the South American republics, they were settled by the authority of the American Government in a manner which was most conclusive.

If you will permit me, I will read to you a passage upon that subject from a correspondence which took place between the United States Government and that of Spain in the year 1816. In that year there existed in South America a state of insurrection against Spain. There were various small communities which had rebelled against the authority of Spain, and were carrying on a petty warfare, in which there were hundreds rather than thousands engaged on one side and the other. A correspondence took place between the United States

Government and Spain. The Spanish Minister wrote to the Government of the United States, and made several demands. One of the points was this. He said:

"The third and last point is reduced to this—that the President "will be pleased to give the necessary orders to the collectors of the "Customs not to admit into the ports of the United States, vessels "under the insurrectionary flag of Carthagena, of the Mexican Con- "gress, of Buenos Ayres, or of the other places which have revolted "against the authority of the King my master, nor those coming "from them; that they should not permit them to land or sell in this "country the shameful proceeds of their piracy or atrocities, and "much less to equip themselves in these ports, as they do, for the "purpose of going to sea to destroy and to plunder the vessels which "they may meet with under the Spanish flag. This tolerance, sub- "versive of the most solemn stipulations in the treaties between "Spain and the United States, diametrically opposed to the general "principles of public security and good faith, and to the laws of the "nations, produces the most melancholy effects on the interest and "prosperity of the subjects of His Catholic Majesty. Certain it is "that neither Carthagena nor any other place in the Spanish domi- "nions in this hemisphere which has revolted can be in communication "with any power friendly to Spain, since neither on its part, nor on that "of any other government, has their independence been acknowledged, "and it is consequently an offence against the dignity of the Spanish "Monarchy, and against the sovereignty of the King, my master, to "admit vessels from such places manned and commanded by insur- "gents, and armed in the dominions of this Confederation, particularly "as they are all pirates, who do not respect any flag, are justly con- "sidered the disgrace of the seas, and are execrated by all nations."

Now, gentlemen, that seems to me to be language similar to what we have heard in other places more recently. And this is the answer of the American Government to the complaint of the reception by the United States of the revolutionary flag of Spain in their ports. The Secretary of State writes to the Spanish Minister thus:

"In reply to your third demand, the exclusion of the flag of the "revolting provinces, I have to observe that, in consequence of "the unsettled state of many countries, and repeated changes of the "ruling authority in each, there being at the same time several com- "petitors, and each party bearing its appropriate flag, the President "thought it proper some time past to give orders to the Collectors "not to make the flag of any vessel a criterion or condition of its ad- "mission into the ports of the United States.

"Having taken no part in the differences and convulsions which "have disturbed those countries, it is consistent with the just prin- "ciples as it is with the interest of the United States, to receive the "vessels of all countries into their ports, to whatever party belonging, "and under whatever flag sailing, pirates excepted, requiring of them "only the payment of the duties and obedience to the laws while "under their jurisdiction, without adverting to the question whether "they had committed any violation of the allegiance or laws obliga-

"tory on them in the countries to which they belonged, either in "assuming such flag or in any other respects.

"In the differences which have subsisted, too, between Spain and "her colonies, the United States have observed all proper respect to "their friendly relations with Spain. They took no measures to in-"demnify themselves for losses and injuries, none to guard against "the occupancy of the Spanish territory by the British forces in the "late war, or to occupy the territory to which the United States "consider their title good, except in the instance of West Florida, "and in that instance under circumstances which made their inter-"position as much an act of accommodation to the Spanish authority "there as of security to themselves. They have also prohibited their "citizens from taking any part in the war, and the inhabitants of the "colonies and other foreigners connected with them, from recruiting "men in the United States for that purpose. The proclamations "which have been issued by the Governors of some of the States and "territories, at the instance of the President, and the proclamations "lately issued by the President himself, are not unknown to your "Government. This conduct, under such circumstances, and at such "a time, is of a character too marked to be mistaken by the impartial "world.

"What will be the final result of the civil war which prevails "between Spain and the Spanish provinces in America, is beyond the "reach of human foresight. It has already existed many years, and "with various success, sometimes one party prevailing and then the "other. In some of the provinces the success of the Revolutionists "appears to have given to their cause more stability than in others. "All that your Government had a right to claim of the United States "was that they should not interfere in the contest, or promote by any "active service, the success of the revolution, admitting that they "continued to overlook the injuries received from Spain, and remained "at peace. This right was common to the colonists. With equal "justice might they claim that we would not interfere to their disad-"vantage; that our ports should remain open to both parties as they "were before the commencement of the struggle; that our laws regu-"lating commerce with foreign nations should not be changed to "their injury. On these principles the United States have acted."

It appears to me that that is placing the principle upon as clear a basis as can possibly be conceived. This correspondence is of the date of 1815. The recognition of the independence of the South American colonies did not take place till 1822—that is, seven years afterwards. Therefore, this is the principle, laid down in the clearest form by the American Government themselves, of what is the course which ought to be taken by a neutral Government towards parties engaged in war, where, on one side, there is an old established Government, and on the other side an insurrection in arms against it; because at that period there was nothing like consolidation or stability in the South American Republics that would have entitled them to recognition, as independent States, and, as I have said, recognition did not take place until seven years later.

Therefore, there are two things which take place when a war of this character breaks out. First of all, there is the recognition of the belligerency; and, secondly, if their independence should be established, there will be recognition of independence. But those are two different things, and stand on a wholly different footing. A war is carried on in order to establish independence, but you recognize the war before you recognize the independence. Independence is the consequence, and the war is the means to that consequence; but it does not follow because the consequence does not accrue that you are not to recognize the war that is to lead to it. Therefore, belligerency is a question of fact, and it is a question of fact which is to be determined by the neutral Governments upon their own responsibility. They will form their judgment of what is the condition of things, whether it deserves the name of a local insurrection, or whether it has reached the proportions of a civil war.

Now, the American Government at the commencement of the recent war seemed disposed, in the first instance, to treat this great insurrection not as a civil war, but as if it had been a mere act of petty treason. That, however, they soon themselves abandoned. The neutral Governments, who were perhaps more impartial lookers on of the game than they were, had very early come to the conclusion that it was a very much larger affair than the American Government themselves supposed, and required at a very early period to be treated as a war. But the notion of treating matters of this kind upon the footing of a private or a political criminal offence is one which has been condemned by the great French writer Vattel at a very early period. He was writing, no doubt, with reference to the insurrection in the Low Countries, and his remarks are characterised by that clearness and common sense in which French writers are never wanting. He says:—

"When a party is formed in a State who no longer obey the sovereign, and are possessed of sufficient strength to oppose him, or when in a Republic the nation is divided into two opposite factions, and both sides take up arms, this is called a civil war. Some writers confine this term to a just insurrection of the subjects against their sovereign, to distinguish that lawful resistance from rebellion, which is an open and unjust resistance. But what appellation will they give to a war which arises in a Republic torn by two factions, or in a Monarchy between two competitors for the crown? Custom appropriates the term of civil war to every war between the members of one and the same political society. If it be between part of the citizens on the one side, and the sovereign with those who continue in obedience to him on the other, provided the malcontents have any reason for taking up arms, nothing further is required to entitle such disturbance to the name of civil war, and not that of rebellion. This latter term is applied only to such an insurrection against local authority as is void of all appearance of justice. The sovereign, indeed, never fails to bestow the appellation of rebels on all such of his subjects as openly resist him; but when the latter have acquired sufficient strength to give him effectual opposition, and to oblige him

"to carry on the war against them according to the established rules, "he must necessarily submit to the use of the term civil war.

"Sec. 293. It is foreign to our purpose in this place to weigh the "reasons which may authorize and justify a civil war. We have "elsewhere treated of the cases wherein subjects may resist the sove-"reign (book 1, chap. 4). Setting, therefore, the justice of the cause "wholly out of the question, it only remains for us to consider the "maxims which ought to be observed in a civil war, and to examine "whether the sovereign in particular is on such an occasion bound to "conform to the established laws of war.

"A civil war breaks the bonds of society and government, or at "least suspends their force and effect; it produces in the nation two "independent parties, who consider each other as enemies, and acknow-"ledge no common judge. These two parties, therefore, must neces-"sarily be considered as thenceforward constituting, at least for a "time, two separate bodies—two distinct societies. Though one of "the parties may have been to blame in breaking the unity of the "State and resisting the lawful authority they are not the less divided "in fact. Besides, who shall judge them? Who should pronounce on "which side the right or the wrong lies? On each they have no "common superior. They stand, therefore, in precisely the same pre-"dicament as two nations who engage in a contest, and being unable "to come to an agreement, have recourse to arms.

"This being the case, it is very evident that the common laws of "war—those maxims of humanity, moderation, and honour, which we "have already detailed in the course of this work—ought to be "observed by both parties in every civil war. For the same reasons "which render the observance of those maxims a matter of obligation "between State and State, it becomes equally, and even more, neces-"sary in the unhappy circumstances of two incensed parties lacerating "their common country. Should the sovereign conceive he has a "right to hang up his prisoners as rebels, the opposite party will "make reprisal; if he does not religiously observe the capitulations "and all other conventions made with his enemies, they will no longer "rely on his word; should he burn and ravage they will follow his "example, the war will become cruel, horrible, and every day more "destructive to the nation."

It seems to me that that is the language of Christianity and civilisation. It is exactly in order that language of that kind may be addressed to all nations of the world that it is of importance that there should exist a code of International Morality.

Now, as between ourselves and the American Government, it does not rest upon our decision alone in this matter, though it seems to me that the circumstances were sufficiently clear to have placed the matter beyond all doubt, even if we had not, what is always satisfactory in such cases, the distinct admission of the American Government themselves that they were at war. For on the 19th of April, 1861, the President of the United States, President Lincoln, issued a proclamation of blockade of ports of the United States. That proclamation of blockade professed to be founded upon the Law of Nations. Now, by

the Law of Nations, no such thing as a blockade can exist except in virtue of a belligerent right. Therefore, on the 19th of April, the President of the United States, in the most formal and distinct way in which it is possible to make such a statement, stated that he was at war. The English Government issued their proclamation of neutrality upon the 13th of May; that is to say, some three weeks after that assertion had been made by the American Government. It certainly does seem a singular thing that a person who had made one assertion three weeks before should complain of another person making precisely the same assertion three weeks afterwards. I have seen very recently that an American writer says, "You did not know of it at that time." First of all, I should answer, What does it signify whether we did know of it? The only question is, was it the fact? Now if two persons on either side of the Atlantic both come to the same conclusion on the same day, when, of course, neither could have known the conclusion at which the other arrived, it would have been the most conclusive proof of the existence of such a fact. We did not come to our conclusion simply upon the ground that the Americans had come to it. But looking at the whole history of the transaction, looking at the position of the parties, neutral Governments were to judge of how that great convulsion was to be treated. I say that we came less early to the conclusion, and equally justly to the conclusion, that the American Government did, that it was to be treated as a legitimate war.

Now, I must pass over these things rapidly, though I would willingly dwell upon them longer. The next point to be considered is, when you have decided that there is legitimate war existing between two foreign nations, what is the result to neutral powers? At first sight, no doubt, the position of a neutral is one of extreme hardship. Here is a Government which itself remains at peace, which is prosperous and united, which is willing to continue that commerce, upon which the prosperity of this people depends, with other nations; all of a sudden it finds its whole relations altered by a quarrel with which it has nothing to do, which it has not caused, which it cannot stop. Nevertheless, it has been found necessary by the practice of nations, and International Law or International Morality confirms the right, that belligerents should exercise against neutrals certain powers, and that neutrals should consent to endure the exercise of those rights. And until the public opinion of nations alters those views, though they may alter them from time to time with advantage, yet as long as the rule remains, I hope that among all nations of the world those rules will be observed.

I am sure it must be a great consolation to every Englishman, and a source of pride to our common country, that the Law of Nations, as laid down in the text-books, as ascertained by history, and as established by treaties, has never been more rigorously or exactly observed than it has been during the great conflict which has taken place on the other side of the Atlantic. To us I think it may be a source of great pride and satisfaction, because from the peculiarity of our former history, we have been almost universally belligerents. As belligerents, struggling

as we did in the great revolutionary war with France, almost, for existence, against the gigantic and overshadowing power of the empire of France, belligerent rights were certainly practised with a strictness and a severity, I hope not overpassing the law, but certainly going up to its extremest limit. Now that there has come a time when, fortunately, we occupy the position, not of belligerents, but of neutrals, it would have been disgraceful, if in such a situation we had sought to depart from the principles, or had refused to bear the burden ourselves, which on former occasions we had compelled other neutral nations to bear. We have done nothing of the kind, and I do not believe there is one single principle which we insisted upon for our advantage as belligerents, which we have not admitted on the part of the Americans on both sides of the conflict, as against ourselves as neutrals.

The duties of neutrals and the rights of neutrals are correspondent. I am afraid the rights of neutrals are extremely limited, and the duties of neutrals are certainly extremely onerous. Now, the first duty of a neutral is, as indeed his desire is, to have no participation in the war. The second duty of a neutral is to act with absolute impartiality to both parties. That is a duty which is not easy of performance, and certainly is not agreeable in its discharge, because it is certain to give dissatisfaction to both sides. That is inevitably the fate of neutrals in the position which they have adopted for themselves. We have heard some complaints made by those who really do not wish to be neutrals, but who wish to take part either with one side or the other, that our neutrality was "cold." It seems to me it is the very essence of neutrality, that it should be, if not cold, at all events lukewarm. The true position of the neutral is, that he is neither a judge nor a party, he is called by the old writers, "*In bello medius.*" That is to be his position. He is like a man who stands taking no part in a war that is raging about him, but is extremely likely in the course of that war to get some hard knocks which were intended for other people.

It is a singular state of things, no doubt, which arises out of war. One would suppose, as I believe, in ancient times it was really supposed, that there was some very great merit in going to war, and, consequently, that people who discharged that valuable function were entitled to some greater consideration than people who remained at peace. Certainly it does seem a singular thing, that a man who goes to war should have rights against you which he did not possess before, and because you remain at peace, that the rights you previously possessed should be to a certain extent curtailed. That is a paradox which is, however, perhaps more apparent than real. In these matters it is impossible to go any length without taking some few leading, guiding, principles to conduct you in your reasoning. The real truth is, that in the case of all the rights which are exercised by belligerents against neutrals, they are exercised against them not as neutrals, but because their conduct is that of quasi-belligerents. You will find, if you examine the rights which are exercised against neutrals, that they are exercised against them for doing acts which constitute them quasi-belligerents. As, for instance, the seizure of contraband; the right of search, which is exercised for the purpose of seeing whether they are contributing to

the warlike proceedings on the other side; the exercise of blockade; in point of fact, you will find, if you examine the matter closely, a neutral is never interfered with, except on the ground that he is suspected to be a person taking part in the war. That, in fact, reconciles the matter in principle, which might otherwise seem somewhat unintelligible.

The first thing which a neutral has to submit to, after war is acknowledged to exist, is the right of search. Now the right of search does not exist in time of peace. That is one of the matters which was for some time in controversy in International Law, but which may now be taken to be perfectly settled. We endeavoured, not absolutely to contend for the right of search in time of peace, but something very like it with reference to the slave trade. However, in the controversy which took place between England and America on that subject, the matter was entirely winnowed out; and now we may take it as an indisputable proposition in International Law, that there is no right of search in time of peace. When the war took place in America, from that instant, the whole mercantile commerce of the neutral nations of the world became subject to be stopped on the high seas and examined, in order to see whether or not it was liable to seizure. In former days this right used to be exercised in respect of enemy's property on board neutral vessels. Now the right of search remains, in order to ascertain if there is any contraband on board.

I said that the history of International Law is the history of the progress of International Morality and Intelligence, in conformity with the spirit of the age in which we live. Now such a chapter may be found in the declaration of Paris with reference to the principles of maritime war. We may pause upon this for a moment whilst we are on the question of right of search. There has been nothing more agitated between belligerents and neutrals, than the limits of the right of search. In the days of the armed neutrality, which was an experiment over and over again repeated by a combination of nations, principally directed against England, for the purpose of altering the old-established principles of the law of nations and of establishing a new code in favour of neutrals, there were various endeavours made to alter the right of search. The first endeavour made was to cover merchant vessels by a convoy, and to take the guarantee of the convoy that the vessels contained no property the subject of capture, as a substitution for the right of search. Those attempts were defeated by the arms of England. When Nelson went to Copenhagen he blew the armed neutrality out of the water; and in the great maritime convention in 1801, which was made with Russia, and to which Denmark and Sweden afterwards acceded, the law of nations was established upon its former footing, and the principles contended for by the armed neutrality were negatived by a judgment obtained in the European tribunal.

One of the principles which was most contended for was that the goods of an enemy on board neutral vessels should not be liable to seizure. That controversy began as early as the beginning of the last century; it was carried on with great acrimony for a long time. It seems to me, whatever may have been the reason of the thing, that

the argument was entirely in favour of the English view of the question. But public opinion upon that subject has been so changed that at the peace of Paris of 1856, England acceded to the view which had been contended for before by other nations; and the Congress of Paris made this important declaration, which may be taken as practically a sort of reformed code of the Law of Nations affecting neutral rights.

The first article of the Treaty of Paris is—

"1. That privateering is and remains abolished."

To that, as you know, the American Government refused to accede.

The second article is—

"2. A neutral flag covers enemy's goods with the exception of contraband of war."

That is establishing the doctrine for which the armed neutrality contended.

The third is—

"3. Neutral goods, with the exception of contraband of war, are not liable to capture under an enemy's flag."

That is the converse proposition.

The fourth is—

"4. Blockades, in order to be binding, must be effective; that is to say, maintained by a force sufficient, really to prevent access to the coast of the enemy."

I shall have a word to say presently on the subject of blockade, because that is one of the most onerous rights of belligerents against neutrals, and it is extremely important to observe its bearings upon the maritime influence of this country.

But let us say a few words on the subject of contraband. I have said before that the rights of belligerents against neutrals are founded upon the fact of un-neutral conduct on the part of the person who is affected by capture, and consequently that he has forfeited his neutral character, and has entitled the belligerent to treat him as an enemy. Now the carriage of contraband, of course, is a transaction precisely of that character. Goods of contraband are goods which are either directly or indirectly of a nature to contribute to the assistance of the enemy in the war. Of course there is great difficulty in the definition of contraband. One of the great misfortunes of the present state of International Law is that there is no catalogue of contraband. I suppose the Congress of Paris thought it too difficult a question to agree upon, and consequently they left it alone. I do not believe at this moment that it is settled whether coals are, or are not, contraband. I remember in old days a decision of Lord Stowell, in which cheese was decided to be contraband if it was going to a port of military equipment, but not contraband if it was going to a place which was not one of military equipment. These matters are left extremely loose, and consequently are of a nature to raise very difficult and dangerous questions between nations. I remember in the American courts a case was recently decided, in which a ship was condemned on the ground of its carrying a cargo amongst which were a certain number of packages of brass buttons with "C. S. N." on them. The court had, before they could condemn this cago as contraband, to

come to the conclusion that "C.S.N." meant "Confederate States Navy," for unless they came to that conclusion there was nothing to connect the buttons with military equipment, and consequently to constitute them contraband. That the court did come to that conclusion is natural enough; the consequence was that the ship had to pay the costs. This handful of buttons were condemned; at all events there was that amount of contraband on board, and the consequence was that the ship did not get its costs for the detention it had sustained.

It is impossible to pass by this question of contraband without alluding to the celebrated case of the "Trent." You know that Captain Wilkes on that occasion took Mr. Slidell and Mr. Mason out of the "Trent." He thought he was doing an extremely sagacious thing, and he did it after, as he said, going into his cabin and consulting his law book. But, unfortunately, it is not very easy to come to a conclusion upon these questions of law in an instant. He did not come with a very calm spirit to the consideration of the question; and he just happened to miss the material point in this question of contraband. He contended that these persons, being ambassadors coming from the enemy, might be treated as contraband; but the essence of contraband is that it should be going to the enemy. Now, Mr. Slidell and Mr. Mason were not going to the enemy at all; therefore if, instead of being Mr. Slidell and Mr. Mason, they had been cannon charged to the muzzle, and ready to explode on the instant, still, if they were on board a neutral vessel going to a neutral port, it was totally impossible that they could be regarded as contraband.

Then, after the right of search comes the question of the right of capture. The right of capture is a very burdensome right as against neutrals, because it is not necessary in order to justify a capture, that the vessel should have been actually guilty. If there are grounds of reasonable suspicion, the capture is justifiable, and the captor actually gets his costs in the matter. This peculiarity works no doubt with some hardship upon neutrals. At the same time, I am not complaining of it, because it is one that belligerents have always contended for, and without which, perhaps, maritime warfare would be impossible. Again, the decision on questions of capture is made solely in the courts of the belligerent countries. This is a singular rule, no doubt, that the question should be tried in the court of the people most interested in obtaining condemnation; yet so it is.

Now, one of the things which the advocates of the neutral interest on the continent long endeavoured, but entirely failed to establish, and I am very glad they have failed to establish it, was to disturb the jurisdiction of the Court of the belligerent captor of prizes. I think it is of the greatest importance that that jurisdiction should be sustained. For this reason—that after all, the person who is responsible to the neutral is the belligerent sovereign who exercises the right of capture. The belligerent sovereign, or the belligerent government, if it be not a monarchy, is the party responsible for establishing just prize courts, who shall administer the law of prizes equitably and fairly. Consequently, in order to secure that responsibility, it is properly in the court of the belligerent that this question should be tried. If you will allow

me, I will read a few sentences from, perhaps, one of the greatest State Papers on International Law ever written. It is the Duke of Newcastle's answer to the Prussian memorial concerning neutral vessels in 1753. It was, in fact, drawn up by Lord Mansfield, in answer to the then newfangled doctrine set up by the Prussian jurists on this subject. He says:

" *First as to the Law.*

" When the powers are at war they have a right to make prizes of " the ships, goods, and effects of each other upon the high seas, what- " ever is the property of the enemy, may be acquired by capture at " sea, but the property of a friend cannot be taken, provided he ob- " served his neutrality. Hence the Law of Nations is established " that the goods of an enemy on board the ship of a friend may be " taken; that the lawful goods of a friend on board the ships of an " enemy ought to be restored; that contraband goods going to the " enemy, though the property of a friend, may be taken as prize, " because supplying the enemy with what enables him better to carry " on the war is a departure from neutrality. By the maritime law of " nations, universally and immemorially received, there is an established " method of determination whether the capture be or be not lawful " prize. Before the ship or goods be disposed of by the captor, there " must be a regular judicial proceeding, wherein both parties may be " heard, and condemnation thereupon as prize in a Court of Admiralty, " judging by the law of nations and treaties. The proper and regular " court for these condemnations is the court of that State to whom the " captor belongs."

Lord Stowell, in one of his greatest and most celebrated judgments, declared, sitting as Judge in the Prize Court, that he was sitting there not to administer the law of England, or any law known specially to England, but he was there to administer the Law of Nations, and in justice to all nations. That I allude to especially now, because during the course of the recent contest there was an attempt made on the part of the Government of the Confederate States to get rid of that principle altogether, and to maintain that, holding themselves liable to the neutral Governments for any miscarriage of justice, they were entitled themselves by their cruisers to make captures, and to determine the righteousness of such captures; in fact, to take upon themselves the responsibility of condemnation without a Prize Court. That is, of course, a thing which no neutral nation could admit. It was attempted only on the part of the Confederate Government, because they had no ports of their own into which they could carry these vessels for adjudication. That was one of the consequences of their being a weak power at sea. Certainly it was not to the interest of our Government to encourage the introduction of a principle, the clear object of which was to defeat the natural result of maritime superiority.

I must notice another principle which is still contended for. We have conceded that neutral property on board enemy's vessels shall be free. There are persons—the late Mr. Cobden was one, and everything which he said on such subjects was always entitled to

great consideration—who strongly argued in favour of the absolute immunity of private property at sea altogether. That also has been the contention of the American Government, and it was a condition they annexed to their assent to the Declaration of Paris that the Powers who were parties to that Declaration of Paris should agree that all private property at sea was free. I confess myself that I am entirely opposed to any such concession, because one cannot help seeing that in war, unfortunately, the necessary object is to injure and to destroy the enemy as much as possible, and to do that at the earliest period. And in the interest of humanity it is desirable that that should be so, because if you make war easy and not onerous, at least not greatly onerous to people, people will be far more tempted to engage in wars, and far more tempted to prolong them. Consequently, what we desire in war is to make it as onerous to the parties as possible, in order that it may be short and decisive. That seems to me to be a fatal objection to a proposition of this character, and I hope it may never be entertained.

I observe that my time is coming to an end. I have only consequently space for a very few remarks, but I wish to say a word upon the subject of blockade. Now this matter seems to be one of very great interest to this country. There is no country which has derived in former times probably greater advantage from the doctrine of blockade than that which used to be the most powerful maritime nation of the world. I have said before, that in the great maritime treaty of 1801 the doctrines of the armed neutrality were negatived by the genius of Nelson. One of the cardinal points contended for by the armed neutrality was a definition of blockade which practically defeated blockade altogether; because the definition insisted on was that it was to be carried on by vessels "*arrêtes et suffisamment proches*," *i.e.*, that the vessels were to be stationary and close to the shore. In those days it was impossible that vessels should be stationary, or that any blockade should be carried on. It was singular that before the conclusion of that treaty the word "*et*" was changed into "*ou*" in the treaty, and so it became "stationary or sufficiently close." Of course, the word "stationary" was thus virtually got rid of, and disappeared altogether from the definition of blockade. M. Hautefeuille is extremely angry about that, and he calls the English negotiators "*saltimbanques*," for what they had done in altering the "*et*" into "*ou*." However, the definition of blockade remains substantially the same by the Treaty of Paris. It is as follow:—

"Blockades, in order to be binding, must be effective; that is to say, maintained by a force sufficient really to prevent access to the coast of the enemy."

This definition in its terms appears to be new. For there is an ambiguity in the expression "really to prevent access." However, in the recent war it has received a very intelligible explanation. Mr. Mason and the agents of the Confederate Government complained very much of the English Government for admitting the American blockade, because they said it was not effective within the meaning of the definition of the Treaty of Paris. They sent

in a list of vessels; they said these vessels had entered their ports, therefore the blockade was not sufficient to prevent access. But the English Government answered, not merely with great common sense, but with great prudence with reference to the future; they said, "Sufficient to prevent access does not mean that occasionally vessels will not go in, but it means that it shall be such a blockade as to prevent access without very great danger."

Well, gentlemen, we have suffered with sufficient severity from the definition which we have ourselves admitted and allowed to be given of that article. But at the same time I think we may congratulate ourselves upon the fact that, by our experience and by our endurance, one of the most powerful engines of maritime warfare that England may ever have to wield, that of blockade, has remained absolutely intact, and that it stands now exactly upon the same footing that it did in 1801 after Copenhagen, and that the definitions which have been accepted by the English Government are precisely those which we have in time of war thought it necessary ourselves to insist upon. The definition of 1801 was that a blockade was effective when there was evident danger to vessels in entering. That is precisely the basis upon which we have acted in the American blockade. As I have said before, we have often had the opportunity by force of arms of establishing the principles of International Law in our own favour. We have, I hope, throughout this war shewn a constancy and a fortitude of another description; and have established those principles by endurance instead of by force. That, I think, is creditable to this country.

I am sorry that the time does not permit me to go further now. I have been able to touch upon very few points, and I am afraid on them but extremely imperfectly. I wish that I had been able to do more.

The President: Mr. Harcourt, I regret very much that, owing to the season of the year, a larger number of our members has not been present to hear the very interesting lecture which you have been good enough to deliver. I am sure all present will concur with me in thanking you for the information you have laid before us, information of interest to a country like this, and peculiarly so at the present time. We thank you also for the trouble you have taken in getting up this information, particularly when it is known how very much at this season of the year your professional duties occupy your time.

LECTURE.

Friday, June 30th, 1865.

General the Right Honourable THE LORD HOTHAM, M.P., President of the Institution, in the Chair.

W. VERNON HARCOURT, ESQ., ON THE RIGHTS AND DUTIES OF NEUTRALS IN TIME OF WAR. PART II.

I HAVE again to appeal to the indulgence of the Institution for the very imperfect character of the remarks which I am able to offer. I was obliged to apologise on the last occasion, and I have more reason to do so now, in consequence of the pressure of business, which has rendered it totally impossible for me to prepare, in a written form, the remarks which I propose to address to you.

The observations which I purpose to make, were intended to be of the most elementary character, and are calculated only for the use of persons entirely unacquainted with these subjects, which makes me the more regret to see present, gentlemen who are conversant with these matters in the highest degree, and in whose presence I find it difficult to discourse on them.

With these preliminary remarks I will, first of all, refer shortly to a point which I touched upon in my previous lecture to you. On that occasion some allusion was directed to belligerent rights. Since that period I have received an extremely voluminous pamphlet from America, which is principally occupied with abuse of myself; that is always an interesting thing to read, more especially when one has the satisfactory consciousness that it is entirely unfounded in its statements, and baseless altogether in its reasoning. The gentleman, whom I have always treated with great respect, Mr. Bemis, has not thought proper to reciprocate that tone in his remarks. Of that I do not complain, except that I always think among gentlemen of the same profession, it is as well, though of a different opinion, to exercise as far as may be, the courtesies of life. But to pass that over, Mr. Bemis maintains the thesis that the recognition of the belligerent rights at the period at which they were recognised by the Government of Great Britain, was an offence of which America has a right to complain.

Now, I made some remarks upon that subject on the previous occasion, and I called your attention to the conduct of the American Go-

vernment themselves, when placed under very similar circumstances, with reference to the Government of Spain in the war which took place between Spain and her rebellious colonies. And I had on another occasion, in a former place, pointed out that the Americans were not justified in making that a ground of complaint, because on the 19th of April, that is to say, nearly a month before the English declaration of neutrality, they had themselves issued a proclamation of blockade. I had shewn that upon the 10th of May a formal and official document, announcing that blockade, had reached the English Government, and that they did not issue the declaration of neutrality till three days afterwards.

Now, Mr. Bemis says, "that is a pretence, you did not allege that at "the time, and you did not rely upon that." But, he further says, "it must "be untrue, because upon the 6th of May the Foreign Secretary in the "House of Commons stated his intention to recognise belligerent rights "on the part of the South." First of all, my answer to Mr. Bemis upon that point is this: it is utterly immaterial whether we knew that the President would issue a proclamation of blockade or not; the real question is a question of fact—was there a war or was there not? You come to that conclusion from various circumstances; you are not at all dependent upon the question whether or not the American Government recognised the existence of legitimate war. All neutral Governments must form their opinion to the best of their judgments upon the whole circumstances of the case. The manner in which the proclamation of blockade becomes material is this, that it is an admission upon the part of the belligerent Government itself that a condition of legitimate war has arisen. Now an admission of a fact is not necessary to be known to a person who himself arrives at the conclusion that that fact exists. For instance, supposing you arrive at a particular conclusion with reference to a fact affecting a particular person, and you act upon that conclusion, and then, after you have acted upon it, you find that he himself in writing has admitted that that fact so existed, you are entitled to use that admission, whether you knew of it at the time or not, because it proves that the fact did exist, and that your conclusion was in fact a right one. That is really the use made of the proclamation of blockade.

Make even the supposition that the proclamation of blockade had not been made till the 13th of May. Well, in that case of course we could not have known of it on that day. And supposing the American Government had said, "You had no right, on the 13th of May, to issue a pro-"clamation of neutrality, because our declaration of blockade could not "possibly have been known to you;" I should have said, "What does "that signify? Our proclamation of neutrality was founded upon our "conviction that a state of war had arisen. We came to that conclu-"sion on May 13th. How can you say that was an erroneous conclu-"sion, because on the very same day and at the very same moment you "arrived at the same conclusion?" Mr. Bemis is entirely in error when he considers it is the material point whether or not we acted upon that proclamation. We use it now, and properly use it, as showing that the fact did exist, and we had arrived at that conclusion upon legitimate grounds.

But, singularly enough, Mr. Bemis, who, whatever may be his other merits, has not the merit of accuracy to a very great extent, choses to state that we could not have known of it on the 6th of May, which is the day on which he places the declaration of the Foreign Secretary in the House of Commons. I had the file of the "Times" searched the other day, and I find the "Times" setting out, on the 4th of May, the declaration of blockade. Therefore, on the 3rd of May, three days before the very date upon which Mr. Beamis chooses to rest his argument, that proclamation of blockade was known to us. Therefore, my answer is twofold. First of all, I say it is immaterial whether it was known or not, because it is only used as an admission of the fact; and that admission is as good now as if it was made at the time. But, secondly, I say the dates show that the proclamation of blockade was known to us at the time of the issue of our declaration of neutrality. Therefore, that entirely disposes of the whole of Mr. Bemis's argument.

There is another point in his argument which is equally untenable. He chooses to say; "Even if you did know of the declaration of "blockade, the blockade was only something to be in the future." What of that? A man says, I am going to strike you a blow; are you to wait till the blow is struck before you place yourself in a position of defence? How stands the case? On the part of the belligerent Government, there is notice of an intention to exercise the right of blockade against neutrals. Of course, it belongs to the Sovereign of this country to issue a proclamation of neutrality, to inform her subjects of the state in which they are placed. Therefore, if the proclamation of blockade was prospective, why the declaration of neutrality was equally prospective, and was only applied on the condition of war taking place and coming into existence. But it is a singular fact, that on looking through the papers of that day, I have discovered that the first condemnation of an English vessel for a breach of blockade, was for an act committed on the 13th of May, which was the very day upon which the English proclamation of neutrality took place. Therefore, actually, the American Government condemn an English vessel for leaving an American port on the 13th of May, and they complain of us for having declared that a condition of war existed.

Really, when we know that at this very moment one of the grounds upon which America is complaining most bitterly of us, and upon which the friendly relations between the two Governments are most imperilled, is such a ground as that, one really does feel some surprise, and one feels also some satisfaction in being able to appeal to those established principles of International Law, the object of which is to settle upon known rules the disputes between nations, and, consequently, to make peace more probable than it would be if there were no rule on which to rely.

But there is another ground upon which the Americans complain of us; they say, "There may have been a land war in America, but at "all events, the Confederate States had no naval resources. Now, the "recognition of belligerent rights gave them all the advantage of a "State which had a strong nautical power; consequently, by granting

" them general belligerent rights, you conferred upon them benefits to " which they were not entitled." I have in my hand some extracts which I have had made from various papers of the United States' Government. This is a letter from the American Secretary of State, Mr. Quincy Adams, to Mr. Forbes, one of the Commissioners sent by the American Government, to see whether or not the South American Republics had made sufficient progress to entitle them to recognition by the American Government.

The Americans complain very much of the sympathy which has been shown in this country for the South. Whatever may have been done here by individuals, the conduct of the Government has been one of the strictest neutrality. I should like to know what the American Government would have said, if the English Government had sent official agents to each of the Southern States, to see how the war was going on, and whether the time had arrived at which they might be recognised? I should like to know what would have been the language of the American Government if we had done as they did in 1820, when the war had been going on for some four or five years, and two years before the condition of things had arisen which they thought justified them in recognising the independence of the South American Republics. Certainly, they took a course far more friendly to the rebel provinces, than our Government has ever done with reference to the Confederate States.

But with reference to this question of the distinction between naval and land belligerent rights there is this passage in the instructions of Mr. Adams to Mr. Forbes. He writes to him, generally, upon what he is to do in the case of vessels of the revolutionary governments. He says:—

" The performance of these duties will involve also the political " relations between those countries and the United States. In the " progress of their revolution, Buenos Ayres and Chili have, to the " extent of their powers, and, indeed, far beyond their natural means, " combined maritime operations with those of their war by land."

Now, mark this passage:—

" Having no ships or seamen of their own, they have countenanced " and encouraged foreigners to enter their service, without always " considering how far it might affect either the rights or the duties of " the nations to which those foreigners belonged. The privateers " which, with the commissions, and under the flags of Buenos Ayres, " have committed so many and such atrocious acts of piracy, were all " either fitted out, manned, and officered by foreigners at Buenos " Ayres, or even in foreign countries, not excepting our own, to which " blank commissions, both for the ships and officers, have been sent."

Now, that is the language of the American Secretary of State, writing to his own Commissioner in the South American provinces, with reference to the nature of a war which had then been waged for five years, under a concession of belligerent rights to those very provinces by the American Government. For five years the cruisers so described in this letter, received the hospitality, and were placed upon perfect equality of rights in the ports of the American States. Well, Gentle-

men, if that does not dispose of the complaint of the American Government, with reference to such conduct on our part, it really is impossible to understand how precedent or argument can ever be brought to bear.

Passing from that subject, it leads one more immediately to another very interesting and important question. Really, one of the principal reasons that I am here to-day is, because I was asked on the last occasion, why it was that I had not said something on the subject of the American claims in the case of the "Alabama." Of course, that is a large and very important question. I certainly did not attempt on the former occasion to allude to it; and time, I am afraid, will hardly suffice upon the present occasion for me to do anything like justice to it. However, I shall endeavour to offer you a few remarks upon that subject.

Now, I have prepared some remarks for another purpose, which have not been hitherto printed, by which I may, perhaps, be able to throw some light upon that question. I will read them to you:—

"The question of the nature and extent of the liability of the "Government of a neutral nation to a belligerent Government, for "injuries which it has sustained by cruisers equipped within the "neutral territory, for the other belligerent, is one of considerable "interest, and of some complexity. Upon general principles it may be "considered that the injury is primarily a wrong done to the sove-"reignty of the neutral Government, and that the belligerent in law "has no strict claim to redress."

Upon that point will you allow me to make this remark? It is extremely important that in all these discussions you should start from the true principles of the case. One belligerent complains of a neutral, for having allowed the other belligerent to do something. Now, in the first place, acts of this kind are wrongly committed by one belligerent, primarily, against the neutral. For instance, supposing that the belligerent comes into a neutral country and enlists men, without the consent of the sovereign; or supposing that he marches an army through a neutral State, without the consent of the sovereign; those are wrongs done primarily to the neutral nation. It is a violation of his sovereignty. It is as if a man came into my house and obtained an instrument with which he injures you. The injury, in the first place, is clearly to me, into whose house he comes; the injury to you is only indirect. And it is only by an indirect process that you arrive at anything like what may be considered a legal wrong; because in war there are no rights between belligerents: one belligerent has no right, in a legal sense, to complain of what another belligerent does to him. Therefore, between two belligerent parties there is no wrong. But there arises a sort of imperfect character of duty, in the neutral. It is not to the interest of either this country or any great maritime country, to disparage or to deny the existence of a certain kind of obligation on the part of a neutral Government, to prevent two belligerents making the neutral soil or the neutral resources available for the purposes of war.

Now, I say, whatever may be the strict legal doctrine in the matter, (and no doubt the rights of the belligerent as against the neutral in a

strict legal sense, are extremely narrow), I do not think, as a question of policy, it is at all expedient for us, either by precedent or by reasoning, to endeavour to restrict the duties of the neutral in that respect; because it is very plain that a case like the "Alabama" is likely to be injurious to no country so much as to Great Britain. And for this reason the country which has great dockyards and great maritime resources is the country of all others which has an interest in preventing vessels being fitted up by a sort of joint-stock company of nations, by which the inequalities of the weaker may be brought to the level of the strength of the greater. If Great Britain goes to war with any other nation, her advantage is that she can equip three vessels to one equipped by any other nation. Certainly, it is not to our advantage to establish any precedent or principle in international law by which the weaker country should be at liberty to go to neutral nations to supply that defect of naval resources, which is our main and great advantage. Therefore, in arguing the question of the "Alabama," I, for one, either as a lawyer or as a politician, should never seek to cut down the principle that neutral nations ought, as far as they can, to prevent their country being made subsidiary to the purposes of the belligerent. I do it, because I think first of all, as a lawyer, that upon the grounds of international morality, which, I say, is a more correct expression than international law, it ought not to be done; and I do it, eminently, as an English politician, because I believe, that to establish such a precedent as that, would be most injurious to the maritime supremacy of Great Britain.

I proceed thus:—

"The neutral Government is, in the first instance, clearly the only "party who is entitled to decide what measures of redress it shall "pursue for a wrong committed against itself. The question, from "this point of view, is discussed at length in a paper which I have "printed, entitled, 'Belligerent Violations of Neutral Rights,' letters "of Historicus. It is not necessary or desirable, however, to deny "that, in some sense, it is the duty of the neutral Government towards "the belligerent, as well as its own duty and right towards itself, to "repress and restrain such violations of its sovereignty. But it is "impossible to put this duty, at the most, as anything more than that "which is called a duty of imperfect obligation. There are many "duties which it may be, in one sense, a perfectly just man ought to "perform, but which he cannot be held legally liable to perform, and "for the non-performance of which, he cannot be made responsible in "damage. Thus it is the duty of every man to assist, and do good "to his neighbour as much as he can—this is a duty of imperfect "obligation. This is quite a different thing from the duty under which "a man lies not to injure his neighbour, or to pay his just debts; this "is a duty of perfect obligation, for the non-performance of which he "is legally responsible. I may illustrate the sort of duty which in "my judgment a neutral Government owes to either belligerent in "the matter of violations of sovereignty by an example familiar to "lawyers. A bailee, for reward, like a carrier, is under an obligation "to protect and safely deliver goods committed to his charge. He

"cannot plead accident or any circumstance (except a few well "known contingencies) as an excuse for the non-performance of his "obligation. He is, in fact, an insurer of the goods bailed to him. "The case is otherwise with a gratuitous bailee—a person who accepts "the charge of goods, without consideration or reward, is bound to "take reasonable care committed to his charge, but he is not an insurer "of their safety. If they are lost, or perish by circumstances not fairly "within his contract, or in spite of ordinary precautions, he is not "responsible for their loss. Now, I think that the position of a "neutral Government in this matter may justly be compared to that of "a gratuitous bailee. He undertakes he will use ordinary precautions "that no mischief shall accrue to one belligerent from the acts of "another within his jurisdiction. But his liability extends no further, "and if such mischief accrues by the accidents which must occur in "the customary course of things, and the usual chances of human "affairs, he cannot be held responsible. In short, he is not an insurer "of one belligerent against the acts of the other one within his own "territory.

"This view of the question will be found strictly in accordance with "the principle enunciated by American statesmen, and acted upon by "the American courts of law in all cases in which they have been "called upon to deal with such cases of violation of their neutrality.

"The principles applicable to this matter are accurately defined by "Mr. Jefferson, in a well-known despatch addressed to the British "Minister, of the date of September 5th, 1793."

Now the circumstances in which this despatch was written, which is one of very great importance, were these:—As you all know, at the breaking out of the revolutionary war between Great Britain and France, the first thing the French did was to endeavour to equip privateers in the American ports. You also know, from the relations between the United States in the early stage of their existence and France, that the United States were on the most friendly terms with France. There was a most violent democratic feeling in favour of the French Revolution in America, and it was only by the virtue of Washington that a war was prevented between Great Britain and America, on account of the sympathy of the people with the cause of France, and it was only by the action of Government that the equipping of vessels, openly and avowedly, was prevented in America. Now, at that time, the American Government did not like, partly in consequence of their treaties, and partly in consequence of the strong feeling of the people, to interfere with the equipment of privateers by the French emissaries in America. Those privateers were equipped openly and without disguise, and armed by the French Minister, Genet, in America; and several of them sailed and made prizes of English vessels. The English Government made claims upon the American Government for compensation for all vessels taken by the privateers so equipped. A discussion arose, which was ultimately settled by the celebrated treaty, made between Lord Grenville and Mr. Jay in the year 1795, upon this subject. Therefore, on this occasion, which arose in precisely the same form, the principles were then thoroughly gone

into and accurately ascertained, and very fortunately recorded in documents, to which we can appeal, and which, certainly, the American Government cannot dispute.

This is the despatch from Mr. Jefferson with reference to the claims made by England upon America with reference to these privateers:—

"We are bound by our treaties with three of the belligerent nations "by all means in our power to protect and defend their vessels and "effects in our ports, or waters, or on the seas near our shores, and to "recover and restore the same to the right owners, when taken from "them. If all the means in our power are used, and fail in their effect, "we are not bound by our treaties with those nations to make com-"pensation."

First of all, you see, we get rid of the position which the American Government has assumed with reference to us, that we are bound at all hazards to prevent such equipments, and that the mere circumstance of vessels having been equipped and having captured American vessels, entitles them to compensation—all that is at once swept away. The question is put upon this footing, and this footing alone:—Did you or did you not, *bonâ fide*, use such means as were fairly in your power to prevent the thing occurring? because if the thing did occur, in spite of your endeavours to prevent it, then you are not liable to compensation. That is the basis of Mr. Jefferson's despatch.

He goes on:—

"Though we have no similar treaty with Great Britain, it was the "opinion of the President that we should observe toward that nation "the same rule, which, under this article, was to govern us with the "other nations; and even to extend it to captures made on the high "seas *and brought into our ports*, if done by vessels which had been "at war with them."

The American Government under that treaty did undertake, and that is a point very much relied upon by the American Government at this moment, to pay certain compensation to the English Government for captures made by those privateers. But mark the grounds on which Mr. Jefferson puts it. He says:—

"Having, for particular reasons, forborne to use all the means in "our power for the restitution of the three vessels mentioned in my "letter of August 7th, the President thought it incumbent on the "United States to make compensation for them."

Why? Because they had deliberately forborne to use all the means in their power, on account of their relations at that time with the Government of France. Rather than quarrel with the Government of France at that moment, they did not interfere; and not having interfered, having deliberately abstained from interfering, they, therefore, paid compensation.

Mr. Jefferson goes on to say:—

"And though nothing was said in that letter of other vessels taken "under like circumstances, and brought in after the 5th June, and "before the date of that letter, yet when the same forbearance had "taken place, it was, and is, his opinion that compensation will be "equally due. As to prizes made under the same circumstances, and

" brought in after the date of that letter, the President determined that " all the means in our power should be used for their restitution."

The American Government having been, as it were, taken by surprise, and being under embarrassment from their treaties with France, and also from the sympathy of the people for the French cause, during the first year or the first year and a half of the Revolutionary War, had allowed these things to pass, as it were, by default. But from the date of this letter, Mr. Jefferson says, " We have got " a statute passed which will enable us to prevent these things." And mark you, that statute was the statute upon which our Foreign Enlistment Act was framed, and, consequently, we are precisely in the same position.—Mr. Jefferson says, being now determined to prevent these things, and having the means to prevent them, the President has determined that all the means in their power shall be used for their restitution:—

" If these fail us, we should not be bound by our treaties to make " compensation to the other Powers in the analogous cases; he did " not mean to give an opinion that it ought to be done to Great Britain. " But still, if any cases shall arise subsequent to that date, the circum- " stances of which shall place them on similar ground with those before " it, the President would think compensation equally incumbent on the " United States."

" Hence you will perceive, Sir, that the President contemplates " restitution or compensation in the case before the 7th of August; " and after that date, restitution if it can be effected by any means in " our power; and that it will be important you should substantiate the " facts *that such prizes are in our ports or waters.*"

You see, compensation for cases where vessels had been allowed deliberately to escape; restitution if they came within the limits and under the authority of the United States; but no compensation if they had employed all the means in their power to prevent it; nor in any case where the prizes were not brought within the American jurisdiction. My paper now proceeds:—

" The principles laid down in this despatch are simple and satisfactory. " Before the enactment of 1794, which was the first American Foreign " Enlistment Act, the American Executive had, practically, no power " to prevent the arming of cruisers by the French Government within " their ports. The consequence was, that they were induced, as " Mr. Jefferson said, to 'forbear to use all the means in their power' " to interfere with French privateers which were openly armed and " commissioned in their ports by the French authorities. To recur to " the former illustration, they were in the position of the gratuitous " bailee, who should knowingly and voluntarily consent to and permit " the destruction of the goods committed to his charge. Under these " circumstances, the American Government thought themselves bound " to try compensation for injuries which they had not taken ordinary— " nor, indeed, any—means to prevent. But after the passing of the " Neutrality Act of 1794, when the executive were armed with means " to enforce the prohibition to arm in their ports, and when the Govern- " ment had resolved to act on its provisions, the situation of things, as

" described by Mr. Jefferson, was wholly altered. From that date, " they were in a position to take measures for the prevention of " violations of their neutrality, and they determined to do so to the " best of their power. Mr. Jefferson then defines what the limit of " their duty would be in such a case. He does not contemplate that " in all cases those measures will be absolutely efficient; indeed, he " distinctly gives the case in which they should prove ineffectual. " And he says, 'If all the means in our power are used and put into " 'effect, we will make restitution, if it can be effected, of prizes " 'brought into our ports,' but he expressly excludes any notion of " compensation for anything done without the jurisdiction. It is " quite plain that 'all the means in our power' means all the reason- " able precautions which a prudent Government can be justly expected " to employ. It does not mean every possible measure which would " absolutely preclude the possibility of failure. If that was the inter- " pretation, no accident could ever occur—for nothing can be accurately " said to be inevitable, since after the event it can always be shown that " some particular though unforseen precaution might have prevented " it. The American Government themselves had frequent occasion to " claim the benefit of such a common-sense limitation of their obliga- " tions, for in numerous cases to be found in correspondence annexed " to this paper, they affirmed that they had employed 'all the means in " 'their power' to enforce their neutrality, when in fact that neutrality " had been in numerous instances violated. Yet if every conceivable " precaution had been taken, it is clear that in each of these instances " the escape of the illegal cruisers might have been prevented."

And in illustration of that, is the case which I refer to in another place, the case of the "Cassius." That is one of the vessels which was equipped by the French Government. The American Government, having received information that that vessel was so equipped, sent a force of 40 militia in a body to stop it. So daring were the French agents at that time in America, that they actually beat off the American militia, and sailed in spite of them. This vessel escaped, and I believe captured several English and American vessels; at all events, she returned as a legitimate cruiser into the port of Philadelphia; and the American Government, so far from interfering with it, when she was sued by persons in New York for the captures she had made, actually, by the action of the Executive, restored her into the hands of the French Government. With reference to such a case, the American Government in ordering the marshal with a force of 40 militia to intercept her departure, may be said to have used all the means in his power, and *bonâ fide* intended to stop the ship. He failed to do so; yet it is plain if the force had been larger, a measure that was within their power, the attempt to stop her would not have failed.

This point is still more strongly illustrated by a number of cases which occurred between the American Government and the Portuguese Government in 1820, at the period when Portugal as well as Spain were engaged in the war in South America. Now, at that period, innumerable vessels were being equipped in the American ports to cruise against the commerce of Portugal, by Buenos Ayres and the

other republics. The Portuguese Government demanded compensation for the captures made by these vessels. They demanded them at the time. At a subsequent period, when the American Government made some claims, belonging to the same period, against Portugal, Portugal again urged those claims. The American Government absolutely refused to entertain them at all, on precisely the same grounds which I am now pointing out. The case is an extremely strong one, because the American Government sent a fleet to Lisbon in 1851 and 1852, to enforce their claims, and these counter-claims, which were set up by the Portuguese, were, on their part, peremptorily rejected.

Now, the grounds of their claim was set forth in the despatch of the Portuguese Minister to the United States Government in 1850, when the whole matter was under discussion. He says:—

"The undersigned has to present the following statement in support "of the claims of Portuguese subjects against the American Govern- "ment, arising from the captures of Portuguese vessels with their "cargoes, in the years 1816 down to so late as 1828, by privateers "fitted out and equipped in ports of the United States, principally in "that of Baltimore, and assuming to sail under the flag of South "American insurgent States, especially that of Artigas.

"Upwards of 60 Portuguese vessels, with their cargoes, were "captured or plundered, and such ships and cargoes were appropriated "by the captors to their own use.

"The fitting out of these privateers at Baltimore was a matter of "public notoriety, and many of the leading citizens there, including the "sheriff and postmaster, were summoned before the courts as owners "or interested in such privateers.

"It is well known, that the noted Banda oriental chief Artigas held "no seaport, had no ships, no sailors, and the privateers assuming this "unrecognised flag were mostly manned and commanded by citizens of "the United States, and in some instances the officers held commissions "in the navy of the United States.

"The undersigned begs leave to say, and he submits, that it was "the duty of the United States' Government to exercise a reasonable "degree of diligence to prevent these proceedings of its citizens, and "that having failed to do so, a just claim exists on the part of the "Government of Portugal on behalf of its bespoiled subjects against "the United States for the amount of the losses sustained by reason "thereof.

"Mr. De Figaniere would here recall to the Honourable Mr. Webster's "attention the state of the negotiations between the two Governments "on this subject. So early as the year 1816, the Chevalier Correa da "Serra, His Most Faithful Majesty's Plenipotentiary, apprised Mr. James "Monroe, the then Secretary of State, of the illegal armaments in "Baltimore. In March, 1818, that Minister claimed indemnification by "the Government of the United States for the losses sustained by the "Portuguese subjects from the captures made by the said privateers, "to which application the Secretary of State, in a note dated the 14th "of said March, replied that 'the Executive having used all their power "'to prevent the arming of vessels in its ports against nations with

" 'whom it was at peace, and having put into execution the Acts of " 'Congress for keeping neutrality, it could not consider itself obliged " 'to indemnify foreign individuals for losses arising from captures " 'upon which the United States had neither command or jurisdic- " 'tion.' "

The Portuguese Minister is dealing with that argument, and no doubt this is the sort of answer which the American Government would endeavour to address to us:—

"The undersigned willingly admits that if the Executive of the " United States had used all its power to prevent the arming of vessels " within its territory, and their sailing from its ports against the com- " merce of Portugal, no claim could have been set up by or in behalf " of Portuguese subjects against the Government of the United States, " but that the only remedy would have been against the wrong-doers " in the courts of law of the United States. But, in point of fact, the " fitting out of these privateers was so notorious, that by due diligence " on the part of the Government and the officers of the United States, " the evil might have been prevented."

The Chevalier Correa, in another communication, addressed to the Secretary of State, dated July 16th, 1820, renewed his application, and proposed that the United States should appoint Commissioners, " with full powers to confer and agree with Her Majesty's Ministers " in what reason and justice demand."

"In a further letter from that Minister to Mr. J. Q. Adams, dated " 26th August of the same year, the names of the officers of the " navy of the United States are given, who in October, 1818, embarked " and served on board the schooner 'General Artigas.' The said " schooner sailed under the so-called Artigan flag, and cruised for " many months on the coast of Brazil, capturing several Portuguese " vessels, among others the 'Sociedade Feliz,'" which was brought to Baltimore.

"The names of said officers, as given by Mr. Correa, were lieutenants " Peleg and Dunham, of Rhode Island, and midshipman Augustus " Swartout, of New York, and Benjamin S. Grimke, of South Carolina.

"Mr. Adams, in a letter addressed to the Portuguese Minister, " dated the 30th of September, 1820, declines the appointment of Com- " missioners as proposed, and intimates that the Portuguese subjects " who may have suffered wrongs have a remedy in the courts of " justice, but that 'for any act of the citizens of the United States, " 'committed out of their jurisdiction and beyond their control, the " 'Government of the United States is not responsible.' Mr. Adams " adds, that in the war in South America, to which Portugal had for " several years been a party, 'the Government of the United States " 'had neither countenanced nor permitted any violation of neutrality " 'by their citizens.'

I think the American Government will find it difficult to prove that the English Government have ever countenanced or permitted any violation of neutrality by their citizens. It is singular that, at the same moment they should be complaining of this violation of neutrality on the part of citizens of England, they should in the same breath be

complaining of that proclamation of neutrality on the part of the Queen, in which she recommends her subjects to abstain from committing any breach of neutrality.

"The undersigned"—(this again is exactly the tone in which the "Americans are addressing us)—without intending to impute criminal "negligence to the Government of the United States in this matter, "may be permitted to observe that citizens of the United States were "permitted, whilst within their jurisdiction and under the control of "the Government, to fit out armed vessels to go forth from the ports "of the United States, filled with American citizens, to prey upon the "commerce of Portugal."

"His Most Faithful Majesty's Government and the undersigned "will readily admit that the Government of the United States did not "support or countenance these proceedings, which were in direct "violation of the laws of nations and of the United States, but it is "conceived that the American Government was, to a certain extent, "remiss in not using more efforts in suppressing these expeditions, "and that a liability results from that remissness. In April, 1822, "Mr. Jozé A. Greham, Chargé d'Affaires of Portugal, in a letter to the "Secretary of State of that day requires that Commissioners should "be 'chosen by both Governments for the purpose of arranging the "'indemnities, justly due to Portuguese citizens, for the damages "'which they have sustained by reason of piracies supported by the "'capital and the means of the United States.'"

"To this application the Secretary of State replied, on the 30th of "April, 1822, that he could not accede to the appointment of Commis- "sioners for the purpose stated, and says 'It is a principle well "'known and understood that no nation is responsible to another for "'the acts of its citizens, committed without its jurisdiction, and out "'of the reach of its control.'

"Mr. Webster will not fail to perceive that the complaint is really "grounded upon the acts of American citizens committed within the "jurisdiction of the United States, and within the reach of the control "of their Government; that is to say, the fitting out of armaments "within the ports of the United States, to despoil Portuguese "commerce.

"This subject has, since the above date, been repeatedly renewed "verbally, if not in the correspondence of Messrs. T. S. Constancio, J. "Banoro Perura, and Jorlades d'Arumbuja, down to 1835; and upon "the renewal of the old claims of the United States against Portugal, "both the undersigned and his Government have repeatedly adverted "to these long-standing and vastly more important counter-claims."

Then he proceeds to argue the question at still further length, and he concludes in this way:—"Mr. de Figanière begs again to submit, "in the name of his Government, to the Hon. Daniel Webster, the "former proposition, as the only proper course which suggests itself "to his mind, in order to arrive at a just and equitable conclusion of "this long pending matter; that Commissioners should be appointed "to ascertain what Portuguese ships and cargoes were captured by "private armed vessels belonging to ports of the United States, and

"owned, commanded, and equipped by inhabitants of the said States, "and the value of such ships and cargoes, and the damage sustained "by reason of such captures; and that the amount thereof be paid by "the Government of the United States to the Government of Portugal "for the relief of the parties injured.

"It is further submitted that the only questions to be left for the "decision of the Commissioners should be the questions of fact just "adverted to. The correctness of the general proposition laid down "by the Committee on Foreign Relations, in reference to the liability of "the United States for its neglect of the necessary means of checking "privateering or piratical expeditions, will, it is conceived, be readily "conceded by the Government of the present day.

"The only question, then, remaining for determination is, whether "the privateering expeditions from the port of Baltimore and other "ports of the United States might not have been prevented by either "the State or Federal authorities, if that diligence which the nature of "case demanded, had been used.

"It appears to the undersigned that the question can admit of but "one answer, and that in favour of the claims in question.

"A list of some of the captures made by American privateers, sailing "under the so-called Artigan and other South American insurgent flags, "is presented herewith. The value of the ships and cargoes amount, "the undersigned computes, to near 2,000,000 dollars, not including "damage and interest.

"The necessary evidence in support of the claims will be furnished "to the aforesaid Commissioners, who may be appointed to examine "the testimony, if the principle for which the undersigned contends be "admitted, as he trusts it will be, by the Government of the United "States."

The Government of the United States sent a fleet to Portugal to enforce those claims, and they utterly refused to entertain or to listen to that claim on the part of Portugal. They refused to appoint Commissioners; they refused to submit the question to arbitration. Certainly we may ask with some confidence whether, having adopted such a course themselves, they can advance claims which they cannot pretend to rest upon any precedent, and certainly upon no stronger ground than that which they have rejected? That letter so well resumes the nature of the whole correspondence, that, though there are many other letters in the correspondence which are extremely interesting and important in a really elaborate legal discussion of the case, I shall pass them over.

It may be said the American Government were perfectly well satisfied that those charges on the part of Portugal were unfounded, and that in point of fact these vessels had not been equipped within the ports of the United States, and that consequently there was no colour or foundation for the claims of Portugal. That, however, is disposed of, I think, and settled upon the best of all authorities, that of Mr. Adams. I find on the 25th of June, 1822, Mr. Adams, writing to the American Minister at Lisbon:—

"After the invasion by the Brazilian-Portuguese Government of

"Monte Video, and the eastern shore of the River La Plata, a revolu-"tionary government, under the name of the Oriental Republic of "La Plata, and subject to the authority of a military chief, named "Artigas, for several years maintained a defensive war at once against "them, and against the rival revolutionary republic, styled the United "Provinces of La Plata. The latter, the seat of Government of "which was at Buenos Ayres, never came to a state of declared war "with Portugal, but the Republic of Artigas did, and that commander "issued commissions for privateers and letters of marque against the "Portuguese, under which the commerce of that nation was for three "or four years much annoyed. Of the captures made by the priva-"teers, several were brought into the ports of the United States, and "frequent complaints were received from Mr. Correa, that some of "the privateers were fitted out within the United States and partly "manned by their citizens. To these complaints every attention, "compatible with the rights of the citizens of the United States and "with the laws of nations, was paid by this Government. The laws "for securing the faithful performance of the duties of neutrality were "revived and enforced; decrees of restitution were pronounced by "the judicial tribunals in all cases of Portuguese captured vessels "brought within the jurisdiction of the United States; and all the "measures within the competency of the Executive were taken by "that department of the Government for repressing the fitting-out "of privateers from our ports, and the enlisting of our citizens in "them."

Mr. Adams does not say that privateers were not enlisted, because he was not in a position to deny it. He does not deny that captures were made. It is notorious that captures were made. Some fifty or sixty of these privateers were actually equipped, and yet the American Government say they did their best (we do not complain of that, on the contrary, we are with them in that), and having done their best they are not responsible for the evasions of those endeavours which have taken place, or responsible for the consequences of those violations.

The same thing took place with reference to Spain. I will not go into that correspondence, though that was equally important, and founded upon precisely the same principles. But that letter which I have read to you from the Portuguese Minister, practically illustrates the whole question. I proceed again to read from the paper I have prepared:—

"The facts and principles established by this correspondence are of "the highest importance. In the first place, it is not denied that in "the space of a few years some twenty or thirty cruisers were unlaw-"fully equipped, armed, and manned by the American citizens within "the ports of the United States. It is not denied that these cruisers "preyed upon the commerce of Portugal, and made numerous captures. "for which the Portuguese Government never received any compensa-"tion. The principle upon which these claims to compensation were "rejected by the American Government were, (1) that they had used "all the means in their power to prevent the equipping of the vessels

" in question, and yet the use of all the means in their power was not " inconsistent with the fact that some thirty such vessels were in fact " so equipped; (2) they insisted 'it is a principle well known and well " 'understood that no nation is responsible to another for the acts of its " 'citizens committed without its jurisdiction and out of the reach of " 'its control;' (3) they maintained that under such circumstances it " was so clear, 'that no nation can in principle, nor does in practice, " 'hold itself responsible, or consider itself bound to indemnify indi- " 'vidual foreigners for loss by captures, over which the United States " 'has neither control nor jurisdiction,' that they peremptorily refused " to accede to a proposal for a joint Commission to consider the ques- " tion, or even to refer the matter to the arbitration of a third party."

It seems to me that the whole of this correspondence affords a complete answer to the grounds upon which the American Government seek to rest their claim for indemnity in the case of the 'Alabama.' This correspondence establishes the true principle. It would take too long at this moment to go into that careful and minute investigation of the facts which alone could give the discussion any value, and therefore I must beg you to accept from me the conclusion, of which I am satisfied myself, upon the facts:—That there can be no charge brought against the English Government of having been guilty of that kind of negligence which would amount to connivance, because that alone, in my opinion, can form the sound, the proper ground of a claim for compensation. For I do hold this, that if a neutral Government deliberately neglects to prevent one belligerent injuring another within its jurisdiction, that neutral Government ought to be held responsible. I equally hold that if a neutral Government takes those fair and reasonable precautions which ought to satisfy any person that it has acted in good faith, then, if persons, whether they be its own subjects or subjects of foreign nations, succeed—as men always will succeed when actuated by strong interests—in evading laws which are made for the prevention of unlawful acts, then, the neutral Government is not to be held responsible, because consequences have ensued which may be indirectly injurious to the belligerents, but which are primarily offensive itself.

I am sure the English Government have no reason to fear an investigation of the facts of the case, and that they will be able to satisfy, as they ought to be able to satisfy, the American Government; and I am quite sure they will be able to satisfy the civilised world, that in this transaction they have acted with perfect good faith. If the 'Alabama' escaped in spite of the honest intention and endeavour of the English Government to prevent her so escaping, then it is clear as the sun at noon-day, clear upon the principles of law, clear upon precedent, clear upon the most conclusive admission of the American Government themselves, that no compensation can be claimed at the hands of the English Government for the consequences of that act.

Gentlemen, I am perfectly certain that when the question comes to be investigated, that is the conclusion at which all parties will arrive. I certainly, myself, am one of those who have always entertained the highest respect for American lawyers and for American statesmen. I

think we have reason to be proud of a race kindred to our own that has produced men of such eminence in all departments of public life. Whatever may be the language which has occasionally been used on this side or the other side of the Atlantic, which I think all reasonable and fair gentlemen present ought to regret, I believe both nations are governed by a fundamental and hereditary respect for law; and that, ultimately, this question will be amicably settled upon principles which we have no fear to appeal to, and by which the American Government themselves cannot refuse to be bound. The more this question is investigated, the more it will be clear, that we have acted honestly in intention, and lawfully in act; and that the good sense, the good humour, and the good judgment of the American people will prevent them from insisting upon claims which I am quite certain every jurist in the world will pronounce to be entirely without foundation.

The CHAIRMAN: Mr. Vernon Harcourt, I am quite sure I may say on behalf of those who are now present, that we all highly appreciate the valuable information you have laid before us. Those who had the good fortune to be here on the former occasion, felt so much interest in the subject, that a great desire was expressed that you might be prevailed upon to come among us on another occasion further to illustrate the very important subject which you have treated. For myself, and I am sure for others, I only regret that the state of the season and the state of the weather have prevented a greater number of our friends from sharing with us the pleasure we have had, in listening to the important remarks which you have laid before us, and for which in the name of the Institution, I beg leave to offer you our thanks.

Evening Meeting.

Monday, June 5th, 1865.

Rear-Admiral Sir F. W. E. NICOLSON, Bart., C.B., in the Chair.

NAMES of MEMBERS who joined the Institution between the 29th of May and 5th of June, 1865.

LIFE.

Lawrence, The Right Honourable Sir John, Bart., G.C.B., K.S.I., Viceroy and Governor-General of India. 9*l*.

ANNUAL.

Ward, E. B., Lieut. H.M. Bengal Army. 1*l*.
Barber, Harby, Lieut. H.M. 15th Madras N. I. 1*l*.

COLONEL SHAW'S PLAN OF MUZZLE-PIVOTING GUNS.

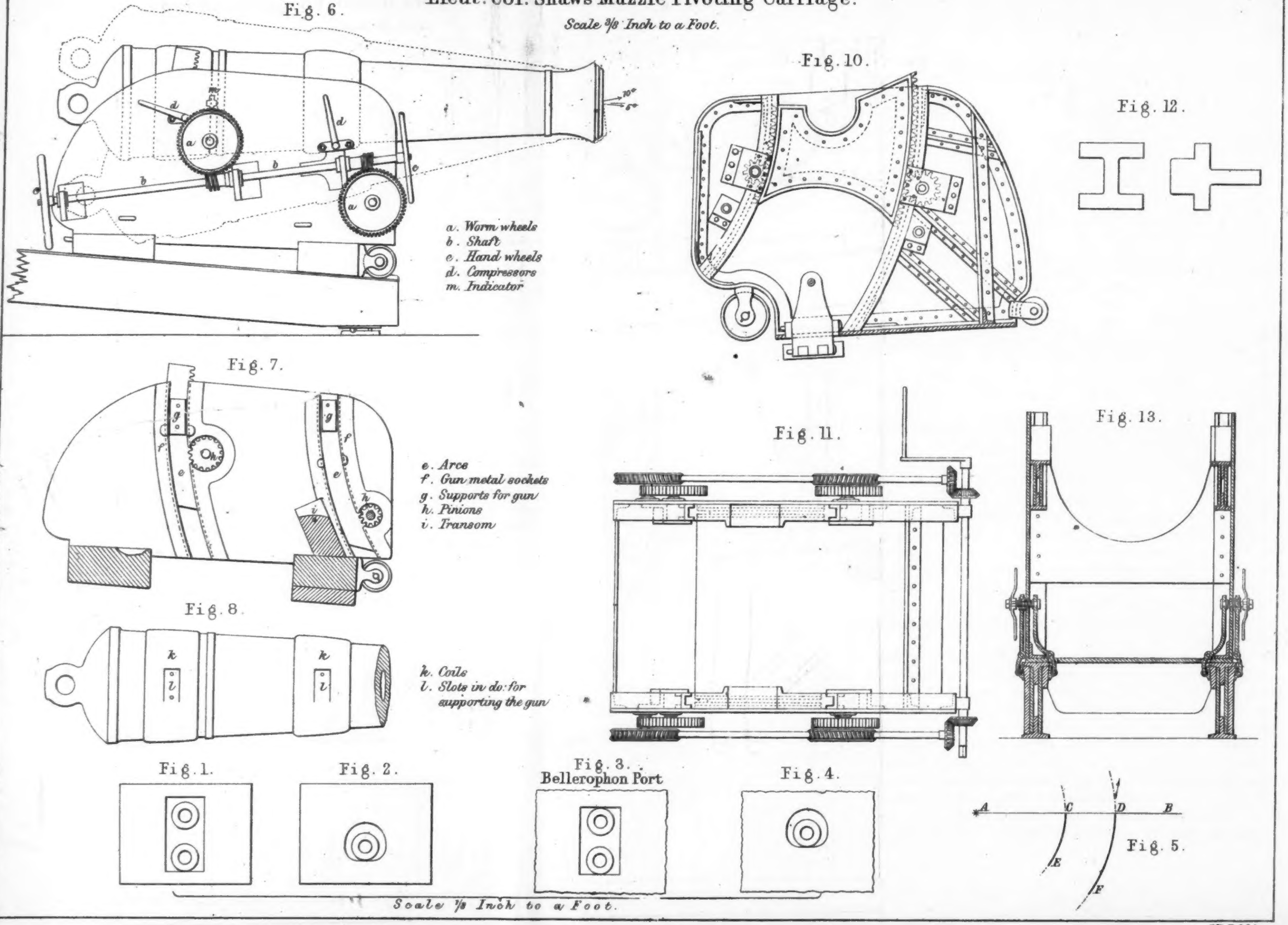
By Lieutenant-Colonel G. Shaw, R.A., Assistant-Superintendent Royal Carriage Department, Woolwich.

Gentlemen,—Having been invited by the Lecture Committee of this Institution to read to you this evening a paper on my system of muzzle-pivoting, I confess I was at first disposed to decline, as I knew the subject to be very dry, and easily exhausted, and I doubted my ability to make it commonly interesting; however, on reflecting that I had introduced this particular system into the Service, I thought it would be churlish of me not to endeavour to impart any information I might have on the subject to my professional brethren; to that end I wrote this paper.

Though this subject is one of great military importance, as far as attack and defence are concerned, it can hardly be deemed one of much general interest, consequently it is a difficult topic to enlarge upon; in fact, when I have told you that the object of this system is to enable us to reduce the size of the ports and embrasures in armour-plated

Lieut. Col. Shaw's Muzzle Pivoting Carriage.

Scale 3/8 Inch to a Foot.



ships and forts to a minimum, without thereby affecting the efficiency of the range of their guns, I have told you nearly all that is to be said in its favour, provided it can be carried out in practice, and of this latter point I hope to convince you this evening before we separate.

As far as I have been able to learn, Mr. Robert Mallet, C.E., has the merit of having been the first to bring this subject to the notice of the Inspector-General of Fortifications, who acknowledged its importance in a military point of view, and referred Mr. Mallet to the Ordnance Select Committee, but for some cause or other they did not consider that his plans could be carried out in practice, and so the matter was suffered to drop for the time.

I was first induced to take this subject up at the instigation of a gallant and talented Officer of the Royal Engineers, who, in a conversation I had with him on the subject of armour-plating for forts, convinced me that to ensure strength and security, it is absolutely necessary to reduce the size of our embrasures to a minimum, and that can only be accomplished by a system of muzzle-pivoting; as it is quite clear that the height of the embrasure cannot be materially reduced, so long as the trunnion remains the centre of oscillation for elevation or depression; in fact, on the present system of elevation, the height of the embrasure depends on the length of the gun from the trunnions to the muzzle, representing the radius of the arc described by the muzzle when elevated or depressed.

An embrasure for a 12-ton gun elevated on the old principle, would have to be 4 ft. 6 in. high by 2 ft. 4 in. wide, so as to allow for a reasonable amount of elevation and depression; and supposing the shield for protecting the casemate to be 6 ft. by 8, the embrasure old pattern would nearly cut it in half, and would only leave a strip of 9 in. of plating above and below which would detract enormously from the strength of the shield (*vide* diagram, Plate xxxiii, Fig. 1), besides the embrasure would offer $11\frac{1}{4}$ feet open area for the admission of shot, shell, and rifle bullets, whereby the gunners might be picked off, and the gun and carriage disabled; and as modern guns and carriages are very expensive articles, it behoves us to protect them by every means in our power. For a 12-ton gun, elevated on my principle I should not require an embrasure to be more than on opening 2 ft. 4 in. in height, and the same in width (*vide* diagram, Fig. 2) thereby affording complete protection to the gunners, gun, and carriage, and adding immensely to the strength of the shield.

In cupola ships on Captain Cowper Coles' plan, the want of a system of muzzle-pivoting is felt still more than in land fortifications, as in them, from their limited height above the deck, it is impossible, having due regard to the strength of the cupola, to have a port more than 2 ft. 9 in. in height; and to enable the gun, mounted on the ordinary carriage, to fire through this port, at different angles of elevation and depression, the platform on which the carriage is mounted has to be raised and lowered bodily by a very expensive arrangement of screws and wedges; the operation also is very tedious, whereas by adopting my principle the whole of this costly apparatus can be dispensed with, and the port can be considerably reduced. I am now making a 12-ton

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muzzle-pivoting wrought-iron carriage for the turret ship "Prince Albert," the size of the port will be 2ft. 1in., and the platform will be a fixture. In my opinion, this system is peculiarly adapted to this admirable class of ships; the turret itself being sighted, the man who lays the gun does not require to look through the port to get his object on, consequently it may be reduced to the exact size of the muzzle of the gun, thereby adding materially to the strength of the turret, and affording complete shelter to the gun's crew.

You will naturally ask, then why not make the ports in the "Prince Albert" the exact size of the muzzle of the gun? The reason is this, the turret is only 16ft. 6in. in interior diameter, and the gun itself is 11 feet long, so that in order to allow room for recoil, I have to pivot the gun 1 foot in from the muzzle, thereby slightly increasing the size of the port.

It is doubtful whether this system can be applied at present with advantage to broadside ports in iron-clad ships, as owing to the centre of motion being at the muzzle, the breech has to go through a much larger one than when the motion is given from the trunnions; for instance, in a ship of the "Bellerophon" class, a 300-pounder mounted upon my principle would, when at extreme depression, touch the beams; it would, no doubt, add greatly to the strength of the ship's side if the ports could be reduced to half their present size, at the same time the port-sills would be higher out of the water, and the crew would be better sheltered, but to obtain these advantages we must have a greater height between the decks.

The principal objections that have been urged against this principle of elevating, are, first, the slowness of the operation; and, secondly, so reducing the size of the port that the captain of the gun has not sufficient field of view to distinguish clearly the object at which he is aiming.

To the first of these objections, I attach little or no importance, as in actual warfare, sudden and rapid changes of elevation can never be required, and even if a sudden emergency did arise, it could be easily met, as in carriages constructed for muzzle-pivoting, the operations of elevating and loading can go on simultaneously, as I will explain hereafter.

The second objection I freely admit; it being quite certain that better practice is to be made from guns mounted en barbette, than from guns in casemates, firing through embrasures only a few inches larger than their muzzles; but if we expect perfect protection for our gunners, guns, and carriages, we cannot expect an unlimited field of view; however, as I propose leaving a space of 6 inches over the gun, which will be constant, I think the field of view will be quite as good if not better than it is at present in our iron-clad ships, where, when firing with extreme elevation, it is absolutely nil (*vide* Diagram, Fig. 3).

For all these reasons I came to the conclusion that our system of artillery would not be complete until muzzle-pivoting should be added to it. I consequently set earnestly to work to devise some practical method of pivoting guns at the muzzle, and in November, 1863, I laid before the Ordnance Select Committee a scheme for working a 68-

pounder 95 cwt. gun on this principle on an ordinary casemate platform to give 10° elevation and 5° depression.

The Ordnance Select Committee approved of my proposal, and I was given a 68-pounder gun and ordered to make a carriage for it.

I will endeavour now to explain my system of muzzle-pivoting; first, the principle upon which I obtain the motion; and, secondly, the application of that principle to practice. Before going further into this question, I must explain that any material support or pivot to the muzzle of the gun would be quite inadmissible; as in the first place, it would be putting the working pivot of the gun in its most vulnerable point, thereby rendering it liable to injury at any moment and, secondly, it would interfere with the working of the gun, as it would prevent its being run out in the embrasure or port. The pivot must be, so to say, imaginary, that is, the muzzle of the gun must be kept stationary, whilst the gun itself is being elevated or depressed, without any material support whatever.

From the centre A (*vide* Diagram Fig. 5) describe two concentric circles, and from A draw the straight line A B, cutting the circumferences of these circles at C and D, from the same centre describe the arcs D F and C E; we will suppose these arcs to be attached to the line A B at C and D. Now if the line A B be moved about A as a fixed point, the arcs D F, C E will always move in the direction of the circumferences of concentric circles due to their common centre A, and conversely if the arcs be moved in the direction of the circumferences of the two concentric circles, the point A will remain fixed. I will endeavour to illustrate this by means of a cardboard template I have had prepared of a 68-pounder gun. The axis of the piece coincides with the line A B, the point A being in the plane of the muzzle, and the lines on the arcs attached to the gun coinciding with the circumferences of the concentric circles. Now, if I put a pivot in the point A and move the gun through several degrees of elevation and depression, you will observe that the arcs attached to the gun invariably move in the direction of the circumferences of the concentric circles. It therefore struck me, that if I forced these arcs to move in the direction of the circumferences of circles due to their common centre by means of the concentric guide-pieces here shown, I should be able to dispense with the pivot at A, and the pivot A would remain fixed, and so the gun is pivoted at the muzzle. That, gentlemen, is the theory of my principle of muzzle-pivoting. Now to apply it to practice.

The woodwork of the carriage is put together in the usual way (see Fig. 6). The brackets are of 7 ft. teak, 3 ft. 6 in. high, 7 ft. 2 in. long, with a distance between them of 2 ft. 7 in. The transom is teak and the blocks sabien. On reference to the diagram of the inside of the bracket (see Fig. 7), it will be seen that the concentric circles are represented by gun-metal sockets and the arcs are wrought iron, 6 inches wide and 2 inches thick, toothed in front and made accurately to fit the sockets; of course the centre from which these arcs and sockets are described is at the muzzle of the gun. The sockets are cast with a pinion box and bearing for a shaft to go through to the outside of the bracket.

As the front set of arcs have a smaller radius than the hind set, they

would have to move through a shorter space than the latter when the gun is raised or lowered. This proportion is regulated by the diameter and number of teeth in pinions which work the arcs. In this case the proportion is as 5 to 8; consequently the front set of pinions have a diameter of 5 inches and 10 teeth, and the hind set have a diameter of 8 inches and 16 teeth. The front set of pinions are keyed on a shaft, which goes through both brackets in front of the transom. On the outer ends of this shaft are worm-wheels 16 inches in diameter; the hind set of pinions are not connected by a shaft, but are each attached to a worm-wheel outside the bracket by a short shaft that works in the gun-metal bearing before alluded to.

The worm wheels are worked by a shaft passing under the hind wheels and over the fore. This shaft has a right-handed screw worm for the hind wheel, and a corresponding left-hand screw worm for the front wheel. These shafts are turned by a cast-iron hand wheel at each end two feet in diameter.

The whole of this machinery is geared together by the shaft that connects the two front pinions. A compressor is fitted to each arc, which, when set up, takes the strain off the pinions. The degrees of elevation are marked on one of the worm wheels, and the degrees of depression on one of the hind arcs.

With a power of 30 lbs. applied to each hand wheel, a weight of about 22,400 lbs. can be raised; of course we must deduct the friction, which in this case would be considerable; and in practice the power is not found to be in excess, as nearly six tons dead weight have to be raised whenever the muzzle of the gun is depressed.

The gun is attached to the arcs in the following manner, on the inside of the arcs, and four inches above and below the axis of the gun, solid pieces of wrought iron are forged on 8 inches high, 4 wide, and projecting inside the bracket 1ft. 5in. The gun is prepared to receive these supports by having its trunnions cut off (this is the worst feature in the system, as the gun is thereby rendered worthless for any other carriage), and having wrought-iron coils shrunk on at convenient distances in front and rear of the centre of gravity, and slots cut in the sides of these coils to correspond with the supports on the arcs, these slots being cut at distances from the muzzle of the gun corresponding to the radii of the arcs. These slots are cut through from the lower part of the coil to four inches above the plane of the axis of the gun, where 1ft. 5in. of metal is left to support the gun on the projecting pieces on the arcs.

The gun, when required to be mounted, is slung in the usual way (care being taken to keep it horizontal), and is lowered on the supports on the arcs which have previously been laid at point blank.

As in carriages constructed on this principle, the muzzle of the gun is always the same height from the deck or ground, it can be loaded at any degree of elevation or depression; and as the degrees of elevation are marked on the worm wheel, the operations of loading and elevating can go on simultaneously, by which means much time is saved. Another advantage of this system is that when once the elevation is accurately ascertained any number of shots may be fired without re-

adjustment, which is not the case with guns elevated on the principles which now obtain in the service. This is also the only carriage on which the degrees of depression are noted. Owing to this carriage being altogether of a new construction, and in the absence of special machinery, much of the work had to be done by hand, special tools had to be made and new patterns prepared, so that it was not finished until early in the spring of 1864, when the gun was mounted, and, without further fitting or alteration, was easily worked by four men. It is pivoted exactly at the muzzle.

The gun and carriage were first inspected by the Ordnance Select Committee in the Royal Arsenal, when the gun was worked several times from extreme elevation to extreme depression; the time occupied in the operation was as nearly as possible three minutes and a half. The Committee, on a subsequent occasion, inspected the gun at the proof butt, when it was fired 10 rounds with service charges, of 16 lbs. of powder, and solid 68-pounder shot; the carriage was not the least shaken, and the gun worked quite as easily after as before the firing.

The gun and carriage were then ordered to be sent to Shoeburyness. to be fired 100 rounds, viz., 50 at 10° elevation, and 50 at extreme depression, and to be worked through an arc of 4° after each 10 rounds. I think perhaps the most impartial way of giving an account of the trials of this carriage at Shoeburyness will be to quote from the official Report furnished to the Ordnance Select Committee.

" The recoils varied from 3ft. 9in. with a wet platform, to 2ft. 2in. " with a dry one." Up to the 30th round, the gun worked easily through an arc of 4° ; at the 40th round, the elevating arrangement worked slightly stiff. At the 51st round, the front hand wheel, on the right-hand side, broke off—all the others were cracked; at the 54th round, the left front wheel broke, the gun continued to work easily through an arc of 4° to the 70th round, when worked a little stiffly; at the 95th round, the gun ran down through an arc of 3°. The detachment can work the wheels while the gun is being loaded. Two wheels work almost " as easily as four. The process of depressing is somewhat " tedious. At high angles of elevation the cheeks of the carriage inter- " fere with the lanyard."

The Committee referred this Report to me, and enquired how I proposed to remedy the defects therein set forth. I informed them in reply, that I was present at the trial, and that I observed two radical defects in the application of the power.—1st. The handwheels were too small, and should not have been of cast-iron ; I propose to supply their place with wrought-iron winch handles. 2nd. The driving shafts are not directly connected, so that one can be worked slightly faster than the other, and so cause occasional stiffness. I propose to remedy this defect by connecting the present shafts by a cross shaft, and bevel wheel as here shown. The Committee assented to my proposals, and the carriage was altered accordingly, and again sent to Shoeburyness to be fired 100 rounds, under the same condition as before. For an account of this trial, I will again quote from the official Report :—

" Recoil with 10° elevation 2ft. 6in.

" Ditto 5° depression 4ft. 3in.

"The gun throughout the experiment was worked easily through an "arc of 4° after every 10 rounds.

"The gun detachment consisted of 1 non-commissioned officer and "8 gunners.

"The carriage—as altered—since last trial is greatly improved; "fewer men can work it, and with greater ease. No difficulty of any "kind was experienced, and no signs of weakness appeared anywhere. "The compressors for jamming the toothed arcs acted perfectly.

"To alter the angle from 10° elevation to 5° depression, occupied the "gun detachment $1\frac{1}{2}$ minutes."

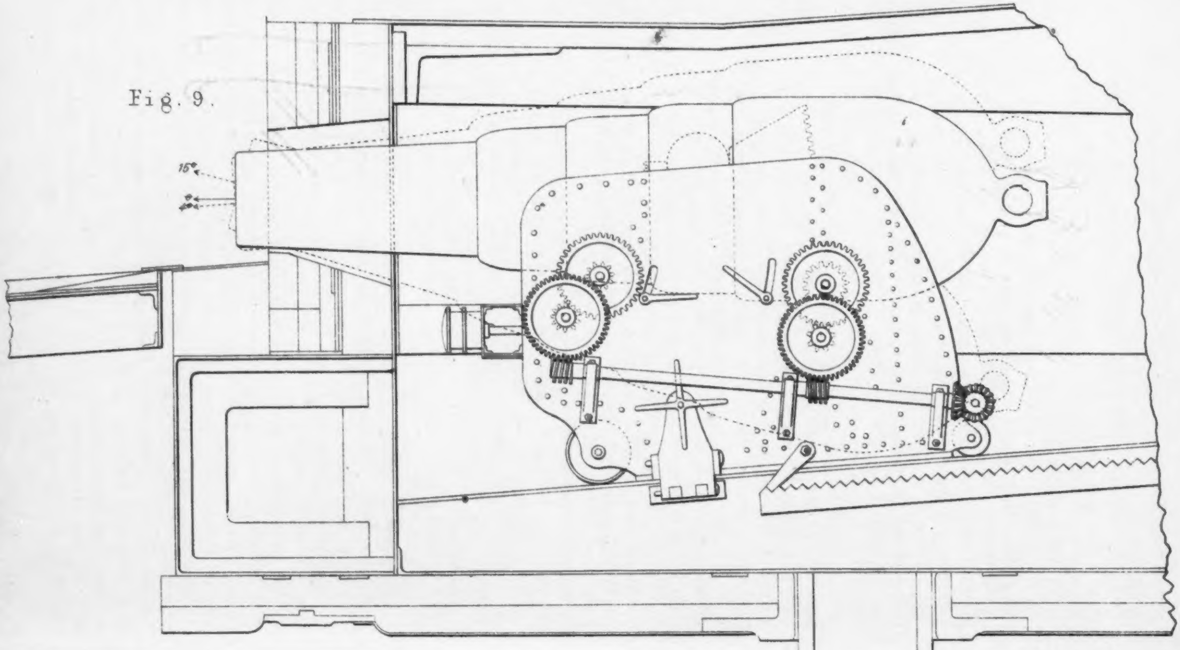
After this severe trial the Ordnance Select Committee had the gun and carriage returned to Woolwich Arsenal, where it now is, and in quite as good condition as when first sent to Shoeburyness; and I shall have great pleasure in showing the carriage to any Officer of either service who may wish to see it. This success of my first attempt at making a muzzle-pivoting carriage, emboldened me to lay before the Ordnance Select Committee a plan for mounting a 12-ton gun (without taking off the trunnions, or mutilating the gun in any way) on a wrought-iron muzzle-pivoting carriage, suitable for working in a cupola. The Committee approved of my design, and recommended the construction of two such carriages, for trial on board such of H.M. ships as the Lords Commissioners of the Admiralty might appoint. After some correspondence the Admiralty consented to a trial of one on board H.M. turret ship "Prince Albert," now fitting at Woolwich Dockyard. The details of construction of this wrought-iron carriage are very different from those of the wooden 68-pounder I have just described, but the principle of muzzle-pivoting remains the same. With the aid of some diagrams I have had prepared, I will endeavour to describe this carriage to you. Here we have, Plate xxxiv, Fig. 9, a side view of the carriage on its slide, with the gun mounted, and shown at elevation and depression, in the port of the cupola; as I before stated, in this case, owing to the interior diameter of the cupola being only 16ft. 6in., and the gun being 11 feet long, in order to leave reasonable room for recoil, I have been obliged to pivot the gun 1 foot in from the muzzle, which causes the port to be slightly larger than if I had pivoted it exactly at the muzzle. This carriage is constructed in frames of 5in. angle iron, $\frac{7}{8}$in. thick; the bottom is of boiler plate 1in. thick; the sides are of $\frac{7}{8}$in. boiler plate, 4ft. 11in. high, 7 feet long; the transoms are also of $\frac{7}{8}$in. plate; the different stays are of $\frac{7}{8}$in. T iron.

Now to obtain muzzle, or rather 1ft. from muzzle-pivoting, I describe my two concentric circles with radii of 5ft. 2in., and 8ft. $\frac{5}{8}$in. (see Figs. 10 and 11, Plate xxxiii.), and between them I place a girder built of strong T iron, and boiler plate, capable of supporting many tons in front and rear. This girder is bounded by arcs, described with the same radii as the concentric guide pieces. This being done with both brackets, these girders, which you see are provided with trunnion-holes, are tied together with a strong iron band, fitted to the shape of the gun, and so form a moveable cradle for the gun to rest in. The section of the arcs in front and rear of the girders is of this form , the projecting

Lieut. Col. Shaw's Muzzle Pivoting Carriage.

Scale 3/8 Inch to a Foot.

Fig. 9.



portion being toothed, and the section of the concentric guide pieces is  so that one section fits exactly into the other. That portion of the angle iron between the tops of the concentric guide pieces is cut away (the bracket being proportionately strengthened on the outside), and the cradle is lowered down between the guide pieces, till it rests on the pinions front and rear; these pinions are worked similarly to those in the wooden carriage, with the addition of a toothed wheel to increase the power. The sides are secured to the bottom by means of T iron and rivets, and are tied together by two transoms, which are made as deep as possible, and hollowed out in the way of gun. As the guide pieces have to sustain the shock of the discharge of the gun, they are supported by strong stays of T iron; the whole of the pinion wheels and shafts work in metal bearings, to prevent being set fast, while means are provided for getting readily at all parts for the purpose of cleaning, oiling, and repair. This carriage works upon a slide (Fig. 13), which is, as long as the cupola will admit; it is constructed of T iron and boiler plate, the lower piece of T iron is bolted to the floor of the cupola; the slope of the slide is 4°.

As a breeching rope would be much in the way, a breast chain is substituted for it, to limit the recoil, while a rack on each side of the slide and pauls upon the sides of the carriage, preclude the possibility of the gun running out from a sudden lurch, or any other cause.

The carriage will be run in by an arrangement of tackle, devised by Captain Coles, and already at work in the cupolas of the "Royal Sovereign."

Buffers constructed of India rubber rings are placed on the front of the carriage, to lessen the concussion when the gun is run out.

The compressors for this carriage (Fig. 13) serve a twofold purpose, namely, the usual one of controlling the recoil, and the other of tying the carriage securely down upon the slide; they consist of plates hinged to the bottom of the bracket, with a screw at their upper ends, working in a female thread against the face of the other, their lower ends are fitted with hanging plates, to grip the wooden fittings of the platform, which are slightly tapered towards the lower edge, so that the action of these compressors, when their upper ends are forced outwards, will be not only to grip the wood on the sides of the slide, but also to bring the bottom of the carriage and top of the slide into closest possible contact.

The arrangement for compressing the cradle to the main carriage was difficult to manage, as the only available space where the compressors could act on the cradle at all degrees of elevation and depression is occupied by the pinion and toothed wheels; the only way I could think of to get over this dilemma, was to make the compressors moveable. Their own weight keeps them in place when the gun is fired at elevation, and when fired at depression a stop on the bottom of each girder raises them to their proper position; they act on the cradle and carriage by jamming a small bevelled plate attached to the eccentric lever of the compressor against a similar bevelled plate fixed to the girder, and so tying the cradle to the side plates, by which means the

teeth of the pinions and racks are relieved from the full force of the concussion arising from the discharge of the gun.

I have now brought you to the point where this system is at present. I consider it as yet quite in its infancy, and have no doubt great improvements will be made in it. I do not see why, with proper management, steam power, hydraulic pressure, or compressed air, might not be brought to bear their part in lifting very heavy guns mounted on this principle; but whatever progress may be made in the working of this system, I do not think the fundamental principle of pivoting the muzzle by working the gun on arcs moving in the direction of the circumferences of concentric circles due to their common centre at the muzzle, will be much improved upon. I hope you will not consider that I am wandering from my text, if in connection with this subject I venture to say a few words on the mounting of our very heavy guns. It is my opinion—and I know that opinion to be shared by numbers of our most experienced Officers of Artillery—that all guns of 12 tons and upwards, whether for land or sea service, should be mounted in revolving turrets or cupolas. It is surely a pity to confine the range of these powerful guns to the limited angle of training to be obtained in any port or embrasure; whereas a gun mounted in a turret is completely protected, and, at the same time, has an unlimited range and field of view. This is the only method of mounting a gun that combines these two conditions. Two guns mounted side by side in a turret would be quite equal to six mounted in any other way. It is also my opinion that no gun heavier than 12 tons ought to be mounted on board ship, either in turrets or at broadside. I do not say for a moment that a 22-ton gun could not be worked in a turret in tolerably smooth water, on the contrary, nothing would be easier, and if the gun could be a fixture, like the engine or boilers, there would be little danger; but, unfortunately, to be useful, a gun must be moveable, and the only way to secure it in rough weather is by chains and ropes. Theoretically, chains will not break under certain known pressure; hooks will not draw; blocks will not carry away; but we all know in practice these things do happen. I have seen a chain break with a weight of five tons that ought not to have failed with 30. The very block of the tackle that mounted the 22-ton gun with perfect safety the other day at Woolwich, broke like a carrot when dismounting it, and let the gun go by the run; luckily it fell on soft ground, and no harm was done. I do not think the Captain of the "Prince Consort" would have felt very comfortable if he had had a couple of 600-pounders on board his ship during the gale he met with in the Irish Channel. And why run the risk? What more powerful gun can be wanted than the 12-ton 9·22? It will throw a shell weighing nearly 300 lbs. containing 15 pounds of powder with wonderful accuracy, as far as we can see. Within 1,000 yards, with steel shell, it will sink the strongest iron clad afloat. Far better have two 12-ton guns on board a ship than one 22-ton gun. Two guns form a battery, one does not.

I have now told you all I know on the subject of muzzle-pivoting, and it only remains for me to thank you for the kind attention with which you have listened to a dry and purely professional paper. My

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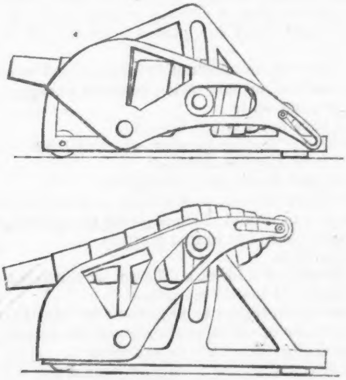
tions. When rolling and pitching, a ship is utterly ungovernable, and would bring strains which, if you use racks and pinions, would never be borne in that way. The same objection applies also to the slide of the carriage as arranged here. We should find more difficulty in adopting the slide on board ship, where it is necessary to have our decks clear to a certain extent for other purposes. It is now in our corvettes. Before the new guns came into play at all, the 68-pounders, when run in for loading, so occupied the whole of the deck, that by no possibility could any manœuvring be carried on. Nor could boarding be so successfully resisted, because the guns made a series of obstacles over which the men would have to jump. Surely these things, which are not at all objectionable in a battery, become extremely objectionable on board ship. I only mention them, hoping to assist Colonel Shaw in arriving at a decision on these points, which he will certainly have to consider when, at a later period, he applies his guns on board ships, and not on cupolas.

Colonel SHAW: I never proposed this for a broadside. It is peculiarly intended for the cupola of the "Prince Albert." The slide is a fixture.

Captain HEATHORN: As regards Colonel Shaw's system of muzzle-pivoting, every artilleryman sees that, in the present day, it is most necessary for cupolas that muzzle-pivoting arrangements should be made. Of course, it has been tried; but I have great doubts whether cog-wheels are not likely to give under the effects of great shocks and very heavy weights. I also think that when a gun is depressed, according to Colonel Shaw's arrangement, there must be very great leverage on the arcs; and also, that under the circumstance of working many hours in grease, dirt, smoke, and all that sort of thing, there would be great friction in working the worm wheels. The machinery is very beautiful; but it is rather complicated for renewing or repairing any part that might be knocked away. I think there might be simpler plans for bringing about the same results. It is most necessary, in any system of muzzle-pivoting, that every available gun should be adapted to the system. And I think the necessity of cutting off the trunnions and shrinking on cylinders and bands, would be a very difficult problem to solve, when, perhaps, one gun was disabled, and you wished to mount another. I have a system of my own for doing the same thing,



which I shall be very happy to explain. The great thing in muzzle-pivoting a gun, is to lift it near its centre of gravity. All the newly-constructed guns are made to balance on their trunnions, which are near the centre of gravity, so I have arranged a fulcrum as near as possible to the gun, lying in the position of its greatest elevation. I have a true carriage, with the trunnion holes brought up in con-

centric arcs, struck with the gun muzzle as centre, and two side wings or levers arranged so that, by applying power at their ends with any jack or screw, I may, according as slots in them are constructed, bring the gun up, by one direct force, in a position of true muzzle-pivoting. And as there is a great necessity for having the weight of the whole machine as near as possible to the deck or to the platform, under all circumstances of firing, I have made a counter-balance on each wing, which, as the gun is lowered to its greatest depression, overcomes the greater difficulty of working, the slots, arranging themselves more obliquely, as the weight of the gun is raised and depression arrived at. Thus I have no more difficulty in working the gun up by oblique slot action than I have by their more direct inclination at the commencement of movement. The accompanying diagrams are worked out by first of all making the trunnion slots in the wings horizontal, and the others conformable. Friction is diminished by friction wheels. There is another thing I should like to point out, that in this case, and in every other on my system, the true carriage takes the recoil in the direct action of the trunnions against the arcs. The lifting is done by the side levers, and working arrangements can be placed in the rear.

Captain KENNEDY, R.N., C.B.: I have seen Colonel Shaw's plan worked at Woowich, and I have nothing to say against it. The only pity is that we have no 22-ton guns. I have lately come from America, where I have seen numbers of 15-inch guns firing 400lb. shot and shell. The weight of the gun was 17 or 18 tons. I have also seen 20-ton guns, and an American officer told me they were going to put them into their ships. If they can carry them, surely we can carry them, and I think Captain Coles' turret will enable us to carry any sized gun used on shore.

Captain BLAKELY: The last speaker but one has given us a very good idea—that of the counterpoise. In two or three years very few nations will use such small guns as those England has at the present moment; and I have no doubt we shall follow the example of America and other nations, and take to very large guns. Therefore, if that should be the case, we shall have to use the counterpoise, or else employ some other power than mere wheels and pinions, or manual labour, which would be almost impracticable. Twelve or thirteen years ago this subject occupied my attention a good deal, as well as that of Captain Simmons, of the Engineers. At that time the plan I proposed was to pivot the gun near the muzzle by putting the trunnions there—not actually at the muzzle, but near enough to reduce the port almost to its minimum size. To raise the gun, I proposed simply to have a small hydraulic jack at the breech; it is a power which a little boy can work well. Its speed depends upon the amount of power; if you put three or four men to work it, they can work it as fast as three or four men at a screw, or a pinion, or anything else. The speed will be in exact proportion to the power, no matter what may be the means of applying that power. Twelve or thirteen years having elapsed since the thing was first proposed, I am afraid it has got rather obsolete. We shall adopt muzzle-pivoting and reduce the size of the ports, just when those improvements become unimportant.

Colonel SHAW: With regard to broadside guns. I have purposely not recommended that anything should be done with these guns for broadside use. The platforms I propose for the cupola will not be suitable for the broadside. I am perfectly well aware of that.

Captain SELWYN: Perhaps you will touch on the point of the centre of gravity being raised.

Colonel SHAW: My centre of gravity is raised slightly when the gun is fired at depression. But that is not the usual angle at which the gun is fired. And when the gun is housed the centre of gravity will be lowered, which will be a very great advantage. This gun is in the cupola. When this gun is housed, it will be down here (pointing), and then there will be lashings through from that to each side of the slide, which will render it perfectly secure. Then, the weight of the gun will be lower than when mounted on the ordinary principle.

Captain SELWYN: We never consider a gun at sea secure unless it is cross-lashed over the gun itself. We should never consider it secure if it were only lashed to the carriage, because our centre of gravity is so much above the point of support as to make it practically useless.

Colonel SHAW: Not in this case, if the gun was lashed through the cascable to ring bolts through the slide close to the deck.

Captain SELWYN: I am afraid no lashings, however low down, would render it secure when the ship was rolling.

Captain KENNEDY: The idea struck me the other day in looking at that gun at Woolwich, how very secure it would be in a gale of wind; it struck me more than anything else, how very secure it would be compared with any other gun I ever saw.

Colonel SHAW: The gun is housed down on deck.

Captain BLAKELY: The gun would be very secure when not in action.

Captain KENNEDY: Of all the points that struck me, the chief was that in a gale of wind the gun would be perfectly secure. What made me think about it the more was, that we had just been examining and cross-examining people on board the "Royal Sovereign" on the very question of securing guns.

The CHAIRMAN: You are all aware that Colonel Shaw is now attached to the Carriage Department at Woolwich, and I am sure we are very grateful to him for having come forward on this occasion, and for the very clear and elaborate manner in which he has placed this subject before us. It is a very technical question, and I think the only way to test these gun carriages is to try them at sea. So far as our own Service is concerned, no amount of trial at Shoeburyness will ever satisfy us as regards a gun-carriage to be worked at sea. I think we all look with some suspicion on cog-wheels, but if these large and heavy guns cannot be worked without something of the kind, we must adopt them. Heavy guns must be worked at sea, we are all agreed about that: whether of 12 tons or more, is another question. I am sure Naval Officers will be delighted if any ingenious gentleman can give us a heavy gun which we can manage to work without elaborate cog-wheels. I have only now to thank Colonel Shaw in the name of the meeting for the very interesting paper he has read.

LECTURE.

Friday, June 23rd, 1865.

CAPTAIN . GARDINER FISHBOURNE, R.N., C.B., Vice-President, in the Chair.

DEEP SEA TELEGRAPHS.

By C. WILLIAM SIEMENS, Esq., C.E., F.R.S.

ON coming forward to address you on the subject of deep-sea telegraphs, it is necessary for me, in the first place, to define my subject by drawing the distinction between deep-sea lines and submarine telegraphs in general.

The characteristics of a shallow sea-line are, firstly, that the iron sheathing usually applied has abundant strength to support the cable during the operation of submersion, as also for raising the same again to the surface for the purposes of repairs; secondly, that it admits of being divided into sections of convenient lengths for the transmission of messages; and lastly, that it lies within reach of abrasion from currents, or even ship's anchors, and has to be made strong enough to resist these mechanical agencies.

The deep sea lines, on the contrary, lie virtually beyond the reach of accident, and in perfect calm at the bottom of the sea; they require, therefore, less absolute strength, but a greater amount of relative strength, to support their own weight in sea water. They generally do not admit of being subdivided into sections, and, therefore, a difficulty arises in regard to them which does not exist in the case of shallow sea cables, respecting the transmission of messages through them at a sufficient rate. Another consideration is that deep-sea cables have to bear a great amount of hydrostatic pressure, and we have to consider what the effect of that pressure is upon the cable. Commercially speaking, we may say that there is this difference between the two cables—that shallow sea cables, or cables which lie in water from 50 to 200 or 300 fathoms deep, have generally proved commercially successful, whereas deep-sea cables, properly speaking, have not done so. In fact, I may say, that at this moment there is not a single deep-sea line which has proved permanently successful.

Within a few weeks the great experiment of a second Atlantic cable

will be repeated, and, it is to be hoped, in the interest of progress and science, as also for the sake of those who have invested so largely in the undertaking, that it may be attended with success. It may, indeed, be safely affirmed that the utmost care has been bestowed upon the manufacture of this cable, and that the chances of its success are infinitely greater than they were on the last occasion, although there may be some reasonable grounds for criticism, particularly as regards the mechanical structure and durability of the outer sheathing. The short space of an hour would not nearly suffice to treat this subject in anything like an exhaustive manner, but I shall, at any rate, endeavour to point out the principal points of interest involved in the construction and treatment of deep-sea cables.

First let me allude to the conductor. This consists generally of a strand of three or seven copper wires, which are twisted together so as to form a metallic rope. Deep-sea cables contain generally only one conductor, as this is sufficient for the purpose of establishing a communication; but multiple deep-sea cables have also been laid with temporary success. The conductor of a submarine cable is the medium of the transmission of the electric current; it also acts as the internal lining of a Leyden arrangement of great length, in which the gutta-percha or other insulating material employed acts the part of the glass jar, and the sheathing of the cable the part of the external tinfoil covering. Considering the extraordinary aggregate surface of long submarine lines, the effects of the change produced by that surface are very considerable. The amount of charge varies according to the surface of the conductors, and is inversely proportionate to the thickness of the insulating material. Therefore, if we could by some means or other double the conductivity of a conductor of a given size, the rate of transmission through the same would exactly be doubled; from which it at once appears how important it is to make a conductor of the least possible size for a given amount of conductivity. The best conductor to answer this requirement would be a single cylindrical wire of silver, which is known to be the best conductor; but a single wire would in the first place be objectionable, because a break or flaw in it would destroy the efficiency of the whole line, and the employment of silver would not be warranted, because a cheaper metal, copper, in its pure state, has very nearly the same conductivity.

The following table shews the conductivities of various metals:—

Table of the Conducting Powers of Metals.

Silver	100	58·2	..
Copper, pure	99·9	58·1	Matthiessen
do. Telegraph	85	49·4	Siemens
do. Rio Tinto	14·2	8·3	Matthiessen
Magnesium	42·3	24·6	Siemens
Iron, pure	16·8	9·8	Matthiessen
Platinum	14·2	8·3	Arndtsen
German Silver	7·12	4·14	Siemens
Mercury	1·72	·1	do.

Taking silver at 100, pure copper is 99·9, or virtually the same. But the

Fig. 1.

VARIATION OF RESISTANCE WITH TEMPERATURE GUTTA-PERCHA (Malta-Alexandria Cable)

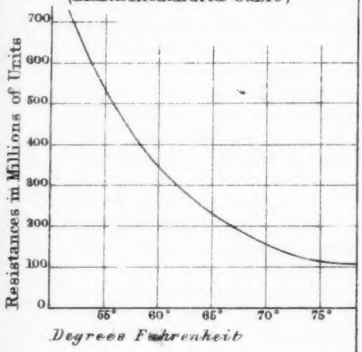


Fig. 2.

VARIATIONS OF RESISTANCES WITH PRESSURE

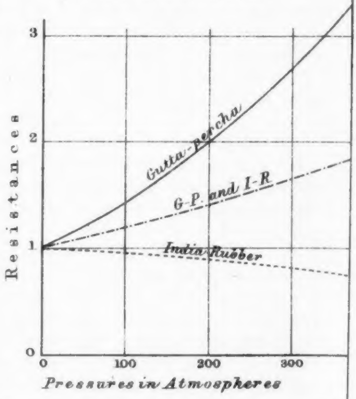
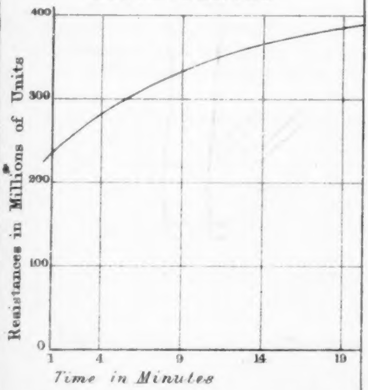
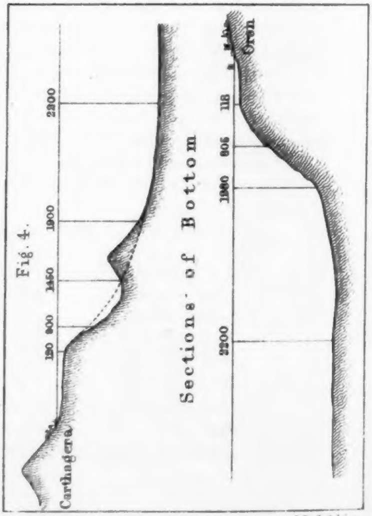


Fig. 3.

VARIATION OF RESISTANCE WITH DURATION OF CURRENT GUTTA-PERCHA





J R Jobbins

best commercial copper we can get at present for the construction of telegraphs has a conductivity of 85. The Burra Burra copper, a good copper of commerce, has only a conductivity equal to 14, owing to a small per centage of foreign matter. From this it appears how important it is to get copper of the highest conductive quality. Since it would not be safe to use a single wire, owing to the risk of a break occurring, we must use a rope of copper wires of the highest conductivity, and it is important that this rope of wires should be as densely united together as possible. Generally seven wires are twisted together, which arrangement, however, might be improved in conductivity for the same diameter, if six smaller wires were laid in between the interstices of the larger ones, the object being to get within a given diameter a maximum amount of conductivity.

We come next to the insulating coating, which may be considered as the vital part of a submarine cable, especially the deep-sea cable. The insulating covering of the conductor is that portion of a submarine cable which requires the greatest amount of care. The insulating substances to be found in nature far exceed in number and amount those which are remarkable for their conductivity, and comprise all the earths, silica, glass, porcelain, sulphur, besides bituminous and resinous substances; yet, notwithstanding this vast field for selection, we have as yet found only two substances fulfilling the collateral conditions of admitting to be moulded upon the conductor into a homogeneous and pliable covering, capable of excluding sea water entirely under great hydrostatic pressure. These substances are india-rubber and gutta-percha.

The substance which was used in the first instance for insulating wire, was india-rubber. It has great flexibility, and its insulating power is very remarkable, but it is a substance which is at no time in a plastic state, therefore considerable difficulties are encountered in dealing with it. Gutta-percha was next tried, and from the time when it was first laid in the harbour of Kiel, in 1848, until the present day, it has been the material used in preference to all others for insulating telegraph wires. The circumstance that gutta-percha, at a temperature of 150 degrees Fahrenheit, becomes semi-fluid, is a great point in favour of its application. It can be put upon wire by a process analogous to the making of maccaroni or of lead tubes, and by putting several coatings of gutta-percha one upon the other, and combining them by intervening thin layers of a fusible compound known as Chatterton's mixture, the most perfect workmanship is produced, the chances of any flaw or leakage in such a coating being exceedingly small.

As regards insulation, pure india-rubber has an insulating power 40 times greater than that of gutta-percha; but notwithstanding this great superiority, the difficulty of putting it upon wire, and certain other drawbacks to which I shall presently allude, have hitherto prevented its application upon a large scale. Gutta-percha has a changeable amount of conductivity, that is to say, its conductivity increases with increase of temperature; the temperature at which it is 40 times more conductive than india-rubber is 75 degrees Fahrenheit. The diagram, fig. 1, shows this remarkable change; the abscissæ represent temperature, and the ordinates relative resistance to the galvanic current.

With regard to the inductive capacity, india-rubber has also the advantage of being superior to gutta-percha in the ratio of 10 to 7.

With regard to fusibility by solar heat, india-rubber has also a decided advantage over gutta-percha, being capable of resisting the heat of boiling water perfectly, whereas gutta-percha softens at a temperature of 120° Fahrenheit, and melts at 130° or 140°. Great care had, therefore, to be used not to expose gutta-percha covered conductors to the direct radiation of the sun or other sources of heat. With regard to hydrostatic pressure, it has been proved that neither india-rubber nor gutta-percha are in the least altered by great pressure; it may, therefore, be safely assumed that they will remain at the bottom of the deepest ocean perfectly unchanged. No doubt there is compression, and this compression has a remarkable effect upon gutta-percha, as I shall presently show. On the occasion of making a line of telegraph for the French Government, which was put into very deep water, I tested gutta-percha and india-rubber also, under pressure, in a tank, of 300 atmospheres, and a remarkable result was produced, as shown by diagram Fig. 2. The insulation at freezing-point and at atmospheric pressure is measured by the ordinate at the starting-point of the curve (on the left), and the succeeding ordinates represent the varying electrical resistances due to increase of hydrostatic pressure. It will be observed that under 300 atmospheric pressures the resistance of gutta-percha was nearly three times as great as under atmospheric pressure. I had expected that india-rubber would follow very nearly the same law, but to my surprise, in the case of india-rubber coated wire, the insulation decreased visibly with increase of pressure, returning, however, always to the original high electrical resistance when the pressure was relieved. I then thought that this decrease might possibly be due to the infiltration of water through the pores of the india-rubber; accordingly, I submitted to the test a wire that had been first coated with india-rubber and then with gutta-percha, the gutta-percha making a complete tube round the india-rubber. This wire followed a law of increase represented by a line between the two, thus clearly showing that we have to deal with a specific quality of the material itself, the precise nature of which has not yet been assigned to any general physical law. For further particulars see Report of the British Association for 1863, page 688.

An important question to be asked in reference to our subject is the following:—Are these substances which we employ for insulating submarine conductors subject to decay? If exposed to air and light they are both very subject to gradual decay, but there is this difference, that gutta-percha becomes brittle by exposure to light and air, whereas india-rubber, at least when put upon copper wire, turns into a viscid liquid and thereby becomes unserviceable; but if submerged, neither of these results takes place; and we may safely affirm that both materials are imperishable when submerged in sea water to any considerable depth. They, nevertheless, undergo a gradual change by absorption of water, unless they are protected by an outer sheathing. Gutta-percha absorbs sea water to a very moderate extent, and in doing so, its conductivity

does not sensibly increase. India-rubber, on the other hand, absorbs water at a somewhat greater ratio, and after a full exposure for 100 days to sea water it absolutely begins to dissolve superficially. An experiment, which was continued over 300 days, clearly establishes this result, and goes to prove, moreover, that the rate of absorption is independent of external pressure. For particulars see Proceedings of Institution of Civil Engineers vol. xxi, page 523. This action may, however, be prevented by the application of an impervious coating, say of tape, saturated with paraffin.

An important advantage in favour of gutta-percha is that joints can be made very perfectly, in fact, joints are now made which are quite equal in insulation to the uniform covering of the wire, whereas, with regard to india-rubber, there is still some degree of difficulty, though I do not mean to say that that difficulty cannot be overcome. There are other substances suitable for insulation which are mostly compounds of india-rubber. A compound of india-rubber and paraffin has been proposed, and its insulation is certainly very remarkable. The compound of india-rubber and sulphur has also a great insulating property, and has the advantage of being capable of being worked in a plastic state before it is hardened upon the wire by application of heat. It must, however, be admitted that gutta-percha answers every purpose of submarine telegraphy if only care is taken not to expose the cable to heat before it is submerged.

We next come to consider the sheathing, and this also is a very important part of the submarine cable. The protecting sheathing is necessary in order to give strength and protection to the delicate insulated core. The sheathing usually adopted consists of one or two layers of tarred hemp or jute, and a helical covering of iron wires, in form of a rope. These wires are generally galvanised, in order to prevent, or rather delay, the oxidation of the iron. In the case of the Persian Gulf cable, the iron sheathing is again covered with jute, impregnated with bitumen mixed with sand, which was applied in the molten state, under the direction of Messrs. Bright and Clark.

In the case of the Toulon and Algiers cable, each wire was previously and separately covered with tarred hemp, and then formed into a rope as usual. This mode of covering did not answer well in that instance, the hemp was eaten rapidly away by marine insects, the xephagala, and there remained only a loose filigree work of wires surrounding the insulated core, offering no protection to the same, and hastening, on the contrary, its failure. A similar sheathing has, I think, unfortunately been adopted for the new Atlantic cable; but it is said, in defence of the same, that the marine animal in question does not exist in the Atlantic, I hope sincerely this may be the case, and also that the great strain which must be brought upon the cable in submerging the same, may not injure the core through the partial unwinding and consequent elongation of the helical sheathing, which must take place, and which constitutes, in my opinion, a very serious objection to the application of such a sheathing for deep-sea lines. Other sheathings for deep-sea cables have been proposed. In one proposed by myself, the core is covered with a double layer of best hemp,

laid on with moderate twist running in opposite directions, under considerable tension. The hemp is covered, while under tension, by a sheathing of copper strips, which, tightly grasping the hemp, prevent its contraction, and it then forms a complete flexible tubing. The copper is mixed with a certain portion of phosphorus, which, according to Dr. Percy's experiments, corroborated by my own experience, is remarkably durable in sea water. A cable of this description has been laid in the Mediterranean, where it now forms one of the links between Algeria and Europe. Small cables of this description have been adopted by the Prussian, Italian, and other Governments, for military purposes, owing to their lightness and strength, combined with remarkable flexibility. The conductor of these cables consists of three steel wires, and its outside diameter does not exceed the eighth part of an inch. In making permanent shallow sea cables on this principle, I apply first an iron sheathing, consisting of comparatively thin wires, and upon that, sheathing just described in which zinc takes the place of the phosphoretted copper. Another covering which has been proposed consists of reeds joined up end to end, and put on like iron wire, producing a rope of very small specific gravity. Different from all these is the cable proposed by Mr. Allen, which has no sheathing whatever, the conductor itself being made strong by being compounded of copper and steel wires. Steel being a very inferior conductor, it is evident that Mr. Allen's cable would not compare favourably for great lengths with others, as regards power of transmission; and for my own part, I should not think it safe to lay down a cable without any external sheathing, which I consider necessary, not only to give strength, but also to protect the insulating material against animals and against abrasion.

We come next to the subject of testing. One of the principal conditions to insure the success of telegraphs, and particularly of deep-sea lines consists in the application of a complete system of electrical testing at every stage of progress of manufacture and submersion. In the early history of submarine telegraphs, this important work was very imperfectly accomplished, and consisted chiefly in methods for the determination of faults, instead of their prevention, and by insisting upon a certain standard of perfection at the different stages of manufacture. For instance, the insulation of the first Atlantic cable was so exceedingly defective before it was coiled on board ship, that it should never have been laid at all, as will be seen from comparison with subsequent cables, shown in the following table:—

INSULATION RESISTANCES OF CABLES.

		Millions.
1857	Atlantic	12
1859	Red Sea	30
1860	Toulon—Algiers	60
1861	Malta—Alexandria ..	120
1863	Bona—Marsala Oran—Carthagena	350
1865	New Atlantic	400

The first Atlantic cable is represented by 12, that is to say, the electrical resistance of the insulating coating of a mile of the cable was equal to 12 millions of (Siemens') units; the Red Sea, by 30; the Toulon and Algiers, by 60; the Malta and Alexandria, by 120; the Bona and Marsala, by 350; and the new Atlantic, by 400, the latter being, however, more thickly covered; so that you see enormous strides have been made without any change of material, simply by increased perfection in the manufacture. But it must also be attributed to the application of proper tests during every portion of the manufacture—tests applied by the engineer who is responsible for the work, and who insists upon a certain standard. In the list to which I have referred, we see that there is a very marked improvement in the case of the Malta and Alexandria line. It may, indeed, be said that this was the first line that was ever made under a proper system of tests. The system then adopted and carried out under my immediate charge (by order of the British Government), has since been applied to other cables with only some modifications of details; and, with your permission, I will give you a short account of what those tests were.

It was determined in the first place that all tests should be referred to a single standard of comparison, this being the resistance of a column of mercury of 1 millimetre sectional area, and 1 metre length at freezing point, which standard is now generally known as Siemens' units, having been first proposed by my brother, Dr. Warner Siemens, of Berlin. Instead of estimating the insulation of the gutta-percha covering by the deflection of a galvanometer, as had previously been done, its conductivity per knot of length was expressed in these units, and values were obtained which were independent of the galvanometer and other testing instruments employed, and admitted of direct comparison between all the results obtained. But the conductivity of gutta-percha varies in an extraordinary ratio with change of temperature, as will be seen by the diagram, Fig. 1, in which the abscissæ represent temperatures, and the ordinates the corresponding electrical resistance; it also varies by electrification of the covering, according to the length of time the current has been active, in the ratio represented in diagram, Fig. 3. In order to obtain standard tests, it was necessary to have them all taken at a uniform temperature, which was fixed at 75° Fahr., being the highest temperature to which the cable was likely to be exposed when laid in a tropical sea. For this purpose the core to be tested was immersed for 24 hours in water-cisterns, which were kept at the standard temperature, when each coil of a mile in length was required to show a gutta-percha resistance of not less than 90 millions of units. The coils of core were then transferred to Reid's pressure tanks, and again tested at the standard temperature, and under a pressure of 600 feet per square inch. I stated before that increase of pressure ought to increase the electric resistance of gutta-percha, and accordingly it was found that there was an increase of something like 20 per cent. each time when the pressure was applied, and unless that increase took place, it was inferred that the gutta-percha coating was not as perfect as it ought to be. Each coil was tested separately, and those that did not

fulfil the conditions insisted upon, were put aside. The actual resistance obtained in each coil carrying a distinctive number was marked against it, and it was then sent to the cable works. There the cable was tested as each coil was added to its length, and it was required that the total resistance of the whole should be equal to the calculated total resistance of all the parts of which it was composed. There correction had to be made for temperature, because it was not found possible to heat the tanks into which the finished cable was received, to the standard temperature. A very perfect core was thus obtained, and the result has proved that though the external covering may be faulty, being an ordinary iron sheathing, the insulation has never given any trouble, and I believe it is now as good as it was at the beginning. The principal instruments used were Professor Wheatstone's bridge arrangement, suitably modified, and Dubois' galvanometer, which is so delicate as to detect exceedingly small traces of electric current; but since then Professor Thomson has brought out a reflecting galvanometer of still greater delicacy, which is now used in preference. In testing the Marsala cable we have introduced another instrument, which combines the functions of the galvanometer and of the bridge. It is a differential galvanometer, one coil of which is mounted upon a carriage, and is moved by a micrometer screw to such a point that the effect of the two currents balance each other. The resistance to be measured forms part of the fixed coil circuit, and as this resistance increases, the second coil must be moved back to diminish its influence also upon the needle. The moveable coil is acted upon by a constant battery, and the extent of motion imparted to it, as read off upon a scale, is the measure of the unknown resistance. It is a very convenient instrument, especially for taking great ranges of resistance.

We now come to the subject of coiling on board ship. The cable on leaving the sheathing-machine, passes into a circular or oval tank, where it is kept covered with water for the convenience of testing, because it is only when under water, that it can be well tested. It is next coiled into circular iron tanks on board ship, from the outside to the centre, then passing sharply from the smaller circle to the larger, then back again in a complete spiral, and so on. Formerly cables were coiled into dry ships' holds, but in the case of the Malta and Alexandria cable, water-tight tanks were first suggested. These were not adopted, however, until it had been proved by means of some special electrical tests, which I had provided, that a spontaneous generation of heat was taking place within the mass of the cable, which threatened to melt its insulating covering. The cable had then to be coiled over into a ship, which was provided with water-tight tanks, and ever since, such tanks have been specially provided.

The CHAIRMAN: Is it so in the Great Eastern?

Mr SIEMENS; Yes, the Great Eastern has been provided with enormous iron tanks to receive the cable. The special means devised to tell the temperature at different points within the mass of the cable, consisted of small coils of insulated copper or platinum wire, encased in iron tubes, which were deposited here and there between the layers of cable, with leading wires from them into the testing-room. The

resistance of each coil at standard temperature being fixed at 100 units, and the law of increase of resistance by rise of temperature of these metals being also known, the temperature of each coil could be easily determined at any time in measuring its electrical resistance. These resistance thermometers might be applied with advantage in many cases where it is desirable to ascertain the temperature of inaccessible places, as for instance, in warehouses and on board ship, where hemp, coals, and other self-inflammable goods are stored.

One of the most important preparatory operations in the laying of cables is that of ascertaining the nature of the ground upon which the cable is to rest, for, however perfect the cable may be, if it is laid upon unknown ground it may very soon come to grief. With regard to shallow seas, there is no difficulty in ascertaining the nature of the ground on which the cable is to rest, whereas in a depth of 2,000 fathoms I have known a single sounding occupy five or six hours. Another drawback as regards deep sea soundings consists in the difficulty of identifying the place again, no landmarks being visible. It must always, therefore, be to a certain extent a matter of uncertainty what is the depth below the ship in the open sea. In going across the Atlantic the depths do not vary materially, as there appears to exist a great plateau on which the cable may be laid; but in deep seas formed by volcanic action, such as the Mediterranean, the depths are very uncertain. It is not impossible, however, that an instrument may be brought to perfection by which the depth below the ship's keel may be indicated in the cabin. Such an instrument would be of material service in warning the telegraphic engineer of changes in the depth of water in paying out deep-sea cables. The few trials which have been made have amply proved the principle of the instrument, and given promise of ulterior success.

The patient care and unremitting attention which the preparation of a deep-sea cable necessitates, in order to avoid the chance of a single flaw or error in the arrangements, contrasts singularly with the exciting operation of submerging the same. A well proportioned cable of ample strength, and a good paying-out apparatus, do much to assure the acting engineer that the cable will sink without being unduly strained either during its descent or after it has reached the bottom; but an entanglement in the cable tank, the breakage of a single wire in the spiral sheathing of the cable, an accident in the machinery employed, or an unknown chasm at the bottom, may at any moment cause the entire destruction of the cherished work.

The machinery employed in paying out cables consists of two principal parts—the guide apparatus and the break apparatus. The guide apparatus consists of a solid cone or cylinder in the eye of the cable, and of a series of iron rings fastened above the cable in crinoline fashion, this being the apparatus first introduced by Newall and Co., and generally employed. The cable, on rising from its coil, is confined in its motion between the cone and the guide rings, and is thereby prevented from twisting round itself and forming kinks. The cable passes through troughs and over pulleys, which should always be well housed, from the hold along the deck, over the brake wheel and a dynonometer wheel, over the stern-pulley into the sea.

A variety of opinions exist with regard to the apparatus which ought to be employed for the paying out of cables, and the amount of retaining force which should be applied, depending in its turn upon the curve which the cable assumes in sinking to the bottom. To my mind it appears perfectly clear that, supposing the vessel to proceed at a uniform rate through the ocean, the line which the cable assumes at any one time during its progress must be a straight line. Suppose you have a cable of the specific gravity of 2, this will descend say 40 feet per minute through the water, falling laterally; and if the ship moves forward 40 feet during that time, the result will be that the cable will assume an inclined direction from the ship to the bottom of the sea without any curvature, forming an angle of 45° with the horizon.

(The CHAIRMAN: To a certain distance, till the terminal velocity is arrived at, there will be a curvature.)

I suppose that the cable assumes its maximum velocity from the moment it touches the water, its acceleration having been accomplished in descending through the air to the water level; in fact, the time for accelerating the speed must be proportionately exceedingly small, considering that a cable may be an hour and a half, or two or three hours, before it reaches the bottom, and that the maximum velocity which the resistance in the water permits it to acquire would be attained by a free fall through 5 feet of space.

The cable is acted upon by two forces, one force tending to drive it down, which is its own absolute weight in sea-water, and is balanced by the resistance to lateral displacement offered by the water; and the second force tending to make the cable slide, by virtue of its own weight in sea water, down the inclined plane which is produced by its position in the water, and which has to be balanced by a retaining force applied to the brake-wheel on board ship. If this cable was left at any one moment to itself it would slide, as you may observe in the case of a stick which is a little heavier than the water in which it descends in a slanting direction. The strain to be applied at the ship must be equal to the tendency of the cable to sliding, and this force can be accurately determined if the depth and the specific gravity of the cable are known. This question has been ably treated in a paper read by Messrs. Longridge and Brooke before the Institution of Civil Engineers. The amount of retarding force to be applied to a cable in paying it out has to be equal to the weight in sea water of the cable in question, reaching from the ship down to the bottom of the ocean, in order to prevent sliding in either direction, but this amount of retarding force has to be varied according to the amount of slack which it is intended to give to the cable when laid. If, for instance, you have a cable of double the specific gravity of water, weighing in water one ton per mile, and pay it out into a depth of two miles, you will have to apply a break-force equal to two tons, or the cable will begin to run overboard with a velocity exceeding that of the vessel through the water.

The CHAIRMAN: Do you know the strength of the Atlantic cable?

Mr. SIEMENS: I do not know exactly the weight in tons. I believe it is equal to supporting 9 or 10 miles of its own weight in water, which is amply sufficient for all purposes.

The angle of descent of a cable is simply the result of the two velocities to which I have referred. If the rate of progress of the ship is four times as great as the rate of descent, there will be an angle of 1 in 4, or $22\frac{1}{2}°$; but if the rates are equal, there will be an angle of 1 in 1, or 45°; or if the ship's velocity is constant, it will be determined wholly by the specific gravity of the cable itself, and the nature of its surface, which will determine its rate of descent laterally through the water. If a cable is simply covered with hemp, its resistance is excessive, as may be easily proved by drawing a hemp rope quickly through water. Such a cable it is difficult to submerge in deep seas with a sufficient amount of slack; it will run out with an inclination of perhaps 10° with the horizon and although the brake may be entirely loosened, it will not slide backward through the water, but will reach the bottom in a straight line, and if there be any irregularities in the bottom, it will have to span them, and be destroyed before long in consequence of a constant strain and complete exposure to corrosive action. Again, if the cable is too heavy, the retaining force would be too great, and serious difficulties would arise. If you suppose a 5-ton cable to be laid to a depth of 2,000 fathoms, a resistance would be required equal to nearly 7 tons. No doubt a sufficiently powerful brake might be constructed, but not even the Great Eastern would be able to make headway with such a retarding force behind it, steamers would have to be used to drag the ship forward; but if any accident should occur, if one of the heavy wires should break, become entangled, the signal "stop" would have to be given, the tug steamers would veer round before the wind, the cable-vessel would be dragged backward by the strain of the cable, and collisions and great mischief might arise. A deep-sea cable, then, must neither be very heavy, nor very light, or it will fail. Experience tends to prove that a cable of from one and a half to twice the gravity of water answers the purpose best. In this respect, the new Atlantic cable is very perfect; it has a specific gravity of about 1·6, combined with great strength; but on the other hand, it is liable to the accidents through broken wires to which all spiral cables are subject, and, moreover, its durability when laid is not likely to exceed that of the Toulon and Algiers cable, which was of the same construction. The cable to which I referred before, sheathed with copper, has about the same specific gravity as the new Atlantic cable, but is free certainly from the above-named objections. I ought not to proceed, however, without alluding to a failure which took place in submerging a cable of this description between Oran and Carthagena last year. Passing over an accident of a purely mechanical nature which occurred in the first attempt, the cable was laid successfully from Oran to Carthagena, a distance of 116 miles, but broke a few hours afterwards, 10 miles distant from Carthagena. According to the soundings which had been previously taken by the French Admiralty in the usual way, the ground presented a moderate incline (shown by the dotted lines on the diagram Fig. 4), but which afterwards turned out to be a great chasm. A cable being laid over a chasm like that, has a poor chance of being taken to the bottom, because whatever slack you may give, and there was 28 per cent. given in this instance, it all slides

down in a straight line, and accumulates at the bottom. Supposing the cable suddenly to touch upon a promontory, it will at once be arrested there and remain suspended in a straight line, because the tenacious mud or ooze which covers the bottom of the ocean, prevents the loose or spare cable on both ends of the suspended piece from sliding towards it to allow of its sinking to the bottom, and the piece of cable thus suspended, under great strain in a catenary curve of perhaps two miles length, must break sooner or later. This cable was, however, partially recovered from a great depth, and has since been submerged between Marsala and Bona, forming a link in the chain of telegraphs which unite France with its African dependency.

It may here be reasonably objected that a cable ought never to have been laid upon such ground, and, further, that if the ground could not be avoided, the soundings ought to have revealed the chasm across which the cable fell, in order that special precautionary measures might have been adopted to meet the case. The answer is, that a line of soundings which had been taken carefully by the French Admiralty showed no such chasm, but that unfortunately the pilot vessel mistook its course during the laying of the cable, and approached Carthagena in a line deviating by about two miles towards Cape Pallos from the line of sounding. The coast about Carthagena, being of a decidedly volcanic formation, might certainly have been avoided altogether, and a much safer landing place might have been found near Cape de Gate, but although this had been strongly urged, it had been refused to the contractors owing to some previous international arrangement which was not to be disturbed. This accident proves, however, the great necessity for careful and more extensive soundings than those which have hitherto preceded the establishment of deep-sea cables; it also goes to prove, that in passing over very irregular ground; it is not sufficient to allow considerably more cable to run overboard than to cover the distance passed over by the cable-ship. The only effective method of laying the cable to the bottom of a chasm would be to stop the vessel over it until the cable assumes a vertical position, and then to proceed slowly onward.

It is desirable that a deep-sea cable should be very flexible, so as to accommodate itself thoroughly to the irregularities of the ground, and in this respect the copper or zinc-sheathed cable leaves little to be desired.

Time does not permit me to enter upon the consideration of untried modes of constructing and submerging cables. The electrical tests applied during the operation of paying-out, and for determining the position of faults in existing cables is a most interesting branch of the science of telegraphic engineering, which I shall also have to pass over on this occasion, referring those interested to the Government Blue Book of 1861, and other sources of information. Nor does time permit me to describe the particular arrangements of instruments for working long submarine lines. Enough I hope has been said to justify the following conclusions:—

1. That the insulating materials now used in the construction of deep-sea cables, are efficient and likely to endure until the protecting sheathing gives way.

2. That for shores and shallow seas, heavy iron-clad cables of from 5 to 10 tons weight per mile have proved practically successful, but that a further protection of the iron wires is desirable to increase their durability.

3. That for deep seas, durability cannot be obtained by weight of iron sheathing, but that a sheathing of moderate weight, which is capable of resisting both the chemical action of sea water and the teeth of marine animals, is requisite.

4. That a hemp covered cable, or a bare insulated conductor, without a metallic sheathing of some sort, is highly objectionable.

5. That the present mode of paying out is safe and efficient under proper management, although capable of further improvement.

Evening Meeting.

Monday, July 10th, 1865.

CAPTAIN E. GARDINER FISHBOURNE, R.N., C.B., in the Chair.

NAMES of MEMBERS who joined the Institution between June 5th and July 10th.

ANNUAL.

Heathorn, T. B., Capt. R.A. 1*l*.
Berkeley, Geo. S., Capt. R.E. 1*l*.
Man, Jno. Alex., Lieut. Royal Aberdeenshire Highlanders Militia. 1*l*.
Bedford, G. A., Capt. R.N. 1*l*.
Curtis, A. C., Lieut. R.N. 1*l*.
England, W. G., Lieut. R.N. 1*l*.
Fletcher, Alex., Capt. 12th Royal Lancers. 1*l*.
Vandeleur, C. T. B., Lieut. 12th Royal Lancers.
Thompson, G. A., Cornet 12th Royal Lancers. 1l.
Burkinyoung, H. H., Cornet 12th Royal Lancers. 1*l*.
Arundell, Hon. E. I. J., Cornet 12th Royal Lancers.
Cockle, Geo. M. A., Capt. Royal Westmoreland Mil.
Davis, Hugh, Lieut. R.N. 1*l*.
Castle, E. J., Lieut. R.E. 1*l*.
Smith, W. H. C., Lieut. 104th Bengal Fusiliers. 1*l*.
Kennedy, G. M., Lieut. R.A. 1*l*.
Lawrence, Geo. St. Patrick, Major-Gen., C.B., Beng. Staff Corps. 1*l*.
Barstow, T. A. A., Ens. 72nd Highrs.
Greenhill, J. G., Asst.-Surg. 72nd Highrs.
Haughton, T., Lieut. R.A. 1*l*.
Willoughby, M. F., Major-Gen., C.B., ret. Bom. Army. 1*l*.
Vaughan, H. B., Capt. 1st Batt. 20th Regt. 1*l*.
Dobie, W. A., Capt. 12th Royal Lancers. 1*l*.
Buttanshaw, W. H., Paymaster, 12th Royal Lancers. 1*l*.
FitzRoy, Rob. O.B., Lieut. R.N. 1*l*.

THE FLIGHT OF PROJECTILES, TOGETHER WITH THE DESCRIPTION OF AN INSTRUMENT CONSTRUCTED BY HIM TO SHOW THE TRAJECTORY OF A BALL FROM A GIVEN ELEVATION AND RANGE, TOGETHER WITH ITS INITIAL VELOCITY AND FORCE OF STRIKING.

A Paper prepared by Major-General ANSTRUTHER, C.B., late Madras Artillery, and read by Major-General J. T. BOILEAU, R.E., F.R.S.

PREFACE.

Extract from "Straith's Memoir of Artillery," pp. 81, 82.

"DR. GREGORY, in his lectures upon gunnery, observes on the differ-
"ence between the times employed by a ball in ascending and des-

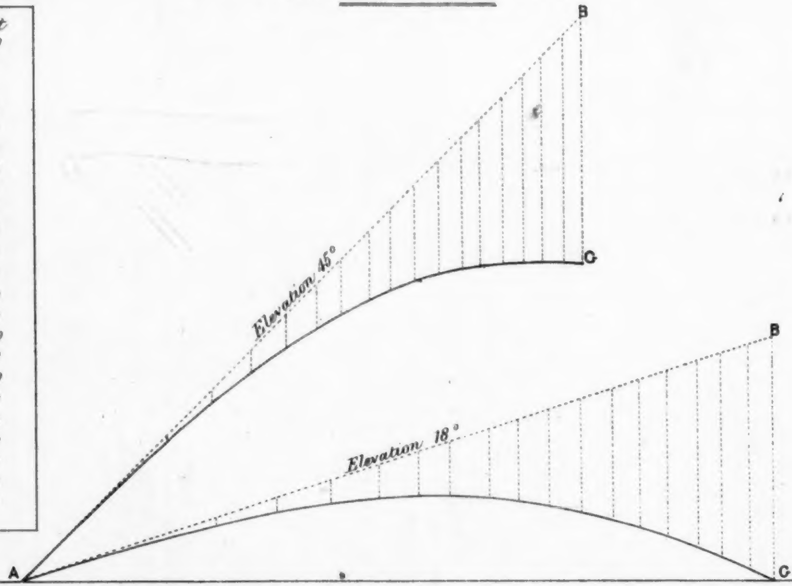
THE TRAJECTORY,

From the "Madras Artillery Records" Vol. 25. No. 1. for January, 1862.

Solid Shot, 68 Pndr Iron Gun, Length 10 feet, Weight 95 cwt. Windage 0.198, Charge 16 lbs. or 0.2353.

GIVEN.

Elevation.	Range.
° ′	Feet
0.15	660
0.30	1020
0.45	1500
1.	1920
1.30	2580
2	3180
2.30	3720
3.	4200
4.	5100
5.	5880
6.	6540
7.	7050
8.	7680
9.	8160
10.	8640
11.	9120
12.	9600
13.	10020
14.	10440
15.	10860
16.	11220
17.	11580
18.	11940



FIND.

A.B.	B.C
660	2.8798
1020	8.9014
1500.1	19.636
1920.3	33.51
2580.9	67.61
3181.9	110.05
3723.5	162.41
4205.8	220.11
5112.5	356.63
5902.5	514.44
6576.	687.38
7103.	865.63
7755.	1079.35
8262.	1292.42
8773.	1523.46
9291.	1772.75
9814.	2040.55
10284.	2313.23
10760.	2603
11248.	2910
11672.	3225
12109.	3540.4
12554.47	3879.54

P. Anstruther, Major General
Late of the Madras Artillery

JR Jobbins

"cending vertically through the same space. If a 24-pound iron ball "were projected vertically upwards, with a velocity of 2,000 feet per "second, it would ascend to the height of 6,424 feet before its upward "motion was extinguished, and it would pass over that space in less "than $9\frac{1}{2}$ seconds. (This is computed in Hutton's Mathematics, vol. 3.) "It might, on a cursory view of the subject, be supposed that the "circumstance of the descent would be analogous to those of the "ascent, but in an inverted order; and so they would, in a non-"resisting medium, but in the air the case is widely different. After "the ball had descended 2,700 feet, the resistance of the air would be "equal to the weight of the ball, there would remain no farther cause "of acceleration, and the ball would descend uniformly with its "*terminal* velocity (that is, the greatest velocity which a heavy body "can acquire when falling in the air), which does not exceed 419 feet "per second. It would require, therefore, $\frac{6424-2700}{419}$ or 6 seconds, to "descend the remaining 3,724 feet, in addition to the time, about 10 "seconds, which had been occupied in descending through the first "2,700 feet; so that, in this instance the time of descent would be "about double that of ascent. In all cases where the projectile "velocity exceeds 300 or 400 feet, the time of descent will exceed "that of ascent; and their difference is greater the more the initial "velocity exceeds that limit."

Section I.

The preface shows what was taught at our artillery academies of Woolwich and Addiscombe as the science of gunnery. We read that a ball, fired vertically upwards with a velocity of 2,000 feet per second, would ascend during a time "less than $9\frac{1}{2}$ seconds," after which, all its upward motion being extinguished, it would descend during "about" 16 seconds, thus making a total time of flight of only $25\frac{1}{2}$ seconds, or less, for this most enormous velocity at the greatest possible elevation. Yet almost every table of recorded practice shows very considerably longer time of flight, obtained at elevations much less than 90°, by the use of moderate charges, therefore with no great velocities. The concluding passage tells us that "*in this instance the time of descent would be about double that of ascent. In all cases where the projectile velocity exceeds* 300 *or* 400 *feet, the time of descent will exceed that of ascent.*" These words inculcate a principle so erroneous that it is impossible to calculate the flight of any projectile until this mistake has been corrected.

Section II.

Whatever the elevation, whatever the velocity, it is impossible that the time of the descent of any ball fired upwards, can be either greater or less than at the time of its ascent, or can be greater or less than the whole time of flight. For, the descent is the motion which is produced by the force of gravity, and this force acts upon the ball from the very moment of its being set in motion, and continues to act upon it during

the whole time of its flight. The second law of motion, rightly understood, teaches this: it tells us that the motion which is produced by the force of gravity acting upon the ball whilst in motion upwards is the same, both in magnitude and direction, as that motion which would be produced in the same time, by the same force, if it were acting upon the same ball suffered to fall freely from a state of rest. Whatever the elevation, whatever the velocity, the ascent and descent of any ball forced upwards must be of equal duration. These two motions may differ in magnitude, and must differ in direction, but they cannot differ in duration; they are simultaneous and not successive; they are synchronous, not consecutive. Hence it follows that if we know the descent we can calculate the ascent; we can graduate the line representing the ascending motion, measuring the initial velocity, and determining the trajectory for that velocity at any elevation whatever. This constitutes the whole science of gunnery.

Section III.

There are three forces acting upon every ball throughout its flight:

I. The projectile force.
II. The force of gravity.
III. The resistance of the atmosphere.

Of these three the first and the second produce motions which we shall take into consideration separately. The third force produces no motion, but acts by reducing the magnitude of the motions produced by the other two forces. Thus, although there are three forces acting, there are only two motions produced, and we have only to compound the motion which is produced by the force of gravity during the flight of the ball with that motion which is produced by the projectile force during the same time, to obtain the actual motion of the ball, its true trajectory, or path through the air.

Section IV.

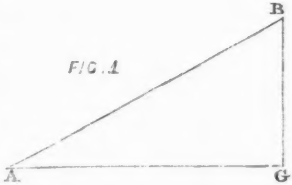
By supposing the angle of elevation to be 90° we throw upon one single vertical line the two motions which we seek to compound, we thus conceal from our own view the fact of their distinct and separate simultaneous existence. We make each of them in succession cover, and so hide, the other. But, by supposing any other elevation, we shall be enabled to employ as a diagram a right-angled triangle, in which the oblique and vertical sides shall represent the two motions which we are to compound, visibly separate and distinct from each other; then, if we can determine the graduation for time of the entire magnitude of each of these two straight lines, we shall be able to draw the true trajectory for any elevation whatever to any degree of minute accuracy that may be desired.

Galileo showed how this was to be done; he proved that the flight of a ball, projected obliquely, must be in the curve of a parabola, "*unless so far as it would be diverted from that track by the resistance of*

the air." But Hutton, followed by Gregory and Straith, taught that the descent commences when the ascent ceases. If this were the case, the motions of every ball would be rectilinear, its angle of descent must always be a right angle, which would render any secoud graze an impossibility, and "*ricochet*" a word without meaning.

SECTION V.

Let A B G, Fig. 1, be a right-angled triangle, within which we are to inscribe the trajectory of a ball, which being fired from A towards B strikes G at the expiration of the time of flight, let us suppose 25·5 seconds, then



I. A B represents the motion produced by the projectile force in 25·5 seconds.

II. B G represents the motion produced by the force of gravity in 25·5 seconds.

III. A G represents the ground over which A B extends.

The curve described by the ball in going from A to G is usually defined by giving the abscissæ and ordinates, the abscissæ being the graduation of A G, and the ordinates, perpendiculars showing the height attained, these are the "internal," measurements of the curve. By this method we require to alter every figure of the calculation for every change of elevation, the consequence is that no one has ever ventured to draw a trajectory for any service velocity with service charge. But if artillerists would define the curve by its "external" measurements, by the graduation of the two lines A B and B G, they would find their advantage in this, that one calculation will serve for all elevations, and that the first space in the graduation of A B denotes the initial velocity at once.

The graduation of A B can only be determined from that of B G which therefore we shall now find.

SECTION VI.

The vertical, B G, is the measure of the fall by gravity in 25·5 seconds of time, we are to find its magnitude and graduation. The fall by gravity in any time, t, is equal to $t^2 \times \frac{1}{2}$ g, where the letter g expresses the velocity which would result from a fall of one second's duration, in a vacuum. The value of g varies slightly according to the latitude of the place, but we shall consider its value, in a vacuum, to be 32·2 feet. The resistance of the atmosphere very greatly alters the value of g, but we have no difficulty whatever in determining the extent of this alteration of value, for thirty seconds or more, and we only require a few experiments, easily made, to raise this to sixty or seventy seconds.

We have a very great number of experiments recorded, in which

the range, elevation, and time of flight are given; we multiply the given range by the tangent of the given elevation; the product is the measure of the fall by gravity in the given time of flight. A careful comparison of very many recorded ranges, &c., led the present writer to adopt the following scale of value for the letter g, and it was offered to the world in a lecture delivered at the Royal United Service Institution in the summer of 1861.

For 2	seconds the fall is	$2^2 \times 16{\cdot}1 = 64{\cdot}4$	feet, the value of g being	32·2 feet.
3		$3^2 \times 16 = 144{\cdot}$		32 ,,
8		$8^2 \times 15{\cdot}5 = 992{\cdot}$		31 ,,
13		$13^2 \times 15 = 2535{\cdot}$		30 ,,
18		$18^2 \times 14{\cdot}5 = 4698{\cdot}$		29 ,,
23		$23^2 \times 14 = 7406{\cdot}$		28 ,,
28		$28^2 \times 13{\cdot}5 = 10584{\cdot}$		27 ,,
33		$33^2 \times 13 = 14157{\cdot}$		26 ,,
38		$38^2 \times 12{\cdot}5 = 18050{\cdot}$		25 ,,

The latter line being uncertain.

The Ordnance Select Committee may be said to have approved and confirmed the principle of the foregoing, as they did, in the winter of 1862, denounce as erroneous the belief which they ascribed to the present writer, that is, a belief that "*the value of g, expressing the fall of an object in the atmosphere under the attraction of gravity, is invariable—always* 32·16 *feet.*"

The latest experiment of which we have any record, the firing at *Shoeburyness*, on the 20th of July, 1864, shows that we are not far wrong, if not perfectly right. The elevation was 23°..9′, and the range 7,300 yards or 21,900 feet. Here the tangent of 23°..09′ ..00″, multiplied by 21900, gives 9363·74 feet, as the measure of the fall by gravity, from which we deduce the time of flight.

We are to determine the time in which a ball will fall through the space of 9363·7392 feet, and we see by a glance at the above table that it is between 23 seconds and 28 seconds; we try 26 seconds and 27 seconds, and we then try 26·1 seconds, and 26·2 seconds, which we find to give as follows, viz:—

$$26{\cdot}1^2 \times 13{\cdot}69 = 9325{\cdot}7649 \text{ feet, } 37{\cdot}9743 \text{ feet, short}$$
$$26{\cdot}2^2 \times 13{\cdot}68 = 9390{\cdot}4992 \text{ feet, } 26{\cdot}76 \text{ feet, over.}$$

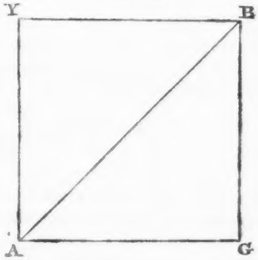
Lastly, we try $26{\cdot}16^2 \times 13{\cdot}684 = 9364{\cdot}5852$ feet, which is only 0·846 feet too long, and this we say is the time of flight for a range of 7,300 yards at an elevation of 23°..9′..00″, Now the "Times" tells us that the observed time was 26·2 seconds, which is 0·04 second more than we should expect, but this suffices to show that the above table is true in principle, and nearly true in fact. The fall for 25·5 seconds of time, by this rule, would be $25{\cdot}5^2 \times 13{\cdot}75^2 = 8940{\cdot}9375$ feet, and this we accept as the magnitude of B G in Fig. 1.

SECTION VII.

Knowing the magnitude of B G and its graduation for time, we can deduce the magnitude of A B for any named angle of elevation, and we shall show how to determine the graduation of A B when its magnitude is known. For convenience of comparison with the tables given in our books, we shall suppose the elevation 45°, and proceed to work out the trajectory from these two data, the elevation, 45°, and the time of flight, 25·5 seconds.

Let A B G, Fig. 2, be a right angled triangle in which the angle B A G is the given elevation, 45°, and the side B G is the fall by gravity for 25·5 seconds, 8940·9375 feet, then we find A G = B G, and A B = A G $\sqrt{2}$ = 8940·9375 $\sqrt{2}$ = 12644·395 feet. Draw A Y, parallel to, and equal to, B G, and join B Y, then is A G B Y a parallelogram, of which A B is the diagonal, and we add to the definitions given in section V, this new one, IV, A Y represents the vertical height attained by A B.

FIG. 2.



We know, from the law of the composition and re-solution of forces, that the force which produces the motion represented by the line A B, is the resultant or equivalent of two forces producing motions represented, both in magnitude and direction, by the two sides A Y, A G, of the parallelogram A G B Y of which said A B is the diagonal. Therefore it is absolutely certain—

First. That the duration of the motion represented by A B, the time during which the projectile force is acting upon the ball, to drive it from A in a direction parallel to A B, cannot possibly be greater than, or less than, the duration of either of the two forces of which it is compounded.

Secondly. That it is impossible that the duration of either one of the two forces of which the force producing A B is compounded can be either greater than, or less than, the duration of the other of the two.

If we can, therefore, determine the graduation of the vertical ascent A Y, we shall be enabled to deduce the graduation of A B, which is the only thing required to enable us to draw the trajectory of the ball.

SECTION VIII.

We have to determine the graduation of the vertical ascent A Y, of which we know the magnitude and the duration. Both in magnitude and duration this motion is exactly equal to the motion represented by the line B G, but the graduation of the descent is invariable, it has

been given in table on page 376, whereas the graduation of the ascent, A Y, varies with the angle of elevation. When the angle of elevation is 90°, when the ball is fired vertically upwards, supposing such a thing possible, then, and only then, would the graduation of ascent be exactly that of the descent, but in an inverted order, and we give in Table A, the graduation of each of the two motions, in juxtaposition, with a column, to show, by the differences between the two, the actual height attained by the ball.

We extract the following from the lecture alluded to above :—"If we "deduct the fall for 25·49 seconds from that for 25·50, the difference "will give the space described by the ball in the last hundredth part "of a second of its fall. It is as follows, viz. :—

"25·50 seconds,	$25{\cdot}50^2 \times 13{\cdot}750 =$	8940·9375
"29·49 ,,	$25{\cdot}49^2 \times 13{\cdot}751 =$	8934·5761151
"a difference of	0·01 second, and	6·3613849 feet, showing a
"velocity of		636·13849 feet per second."

The difference between our calculation and that of Hutton is as follows :—He gives the velocity as 2,000 feet per second ; we say it is 636·1285 feet ; he gives an actual ascent of 6,424 feet ; we say it is 4,056 feet ; he divides the time of flight into two unequal parts ; we say the two motions are simultaneous.

We have said before, that the graduation of A Y, the vertical ascent, varies with the angle of elevation, we shall now show to what an extent this is the case. Suppose the ball fired at elevation to give $1\frac{1}{2}$ seconds time of flight, initial velocity 636·1385 feet per second. We find the elevation thus, say—

as the oblique ascent for 1·5 seconds, 934·5375 feet,
: is to, 90°,
: : so is the vertical descent, for 1·5 seconds, 36·3375 feet,
: the angle of elevation, 2°..13..40, logm. 8·58975836.

We obtain the graduation of the vertical ascent by saying as 90°

$$: \left\{\begin{array}{r} 315{\cdot}9375 \\ 311{\cdot}5375 \\ \underline{307{\cdot}0625} \\ 934{\cdot}5357 \end{array}\right\} \; : \; : \; 2^\circ..13..40 \; : \left\{\begin{array}{r} 12{\cdot}284558 \\ 12{\cdot}113471 \\ \underline{11{\cdot}939471} \\ 36{\cdot}3375 \end{array}\right.$$

The vertical ascent and vertical descent, equal in magnitude and duration, differ very widely in graduation at this low elevation, as the following table will show :—

In each half-second the ascent is	12·284558	and the descent is	4·0625
	12·113471		12·1375
	11·939471		20·1375
	36·3375	Totals, equal—	36·3375

Table B, *Appendix*, shows how to apply table A to any other elevation, less than 90°, drawing the trajectory without any further trouble

in calculating; let it be supposed that the elevation desired is 35°, we draw a right-angled triangle, its angles 90°, 35°, and 55°, and on the hypothenuse we lay off the 36 graduations marked as "*Ascent Feet*" in table B, then let fall 36 perpendiculars showing the "*Descent Feet*" in the same table; then a line joining the lower extremities of all these perpendiculars is the real trajectory or path of the ball.

Before leaving this velocity we shall show its range at 45° elevation. We find, by repeated trials, that the time of flight will be 20·625 seconds, for the ascent in 20·625 seconds is as follows, viz. :—

From $25{\cdot}5^2 \times 13{\cdot}75 = 8940{\cdot}9375$ the possible ascent for this velocity,
Take $4{\cdot}875^2 \times 15{\cdot}8125 = 375{\cdot}7939423125$ the fall in 4·875 seconds, then

20·625 seconds time, 8565·143546875 is the ascent for this time and $20{\cdot}625^2 \times 14{\cdot}2375 = 6056{\cdot}5$ feet, the descent in the same time. Then we say as 9565·14355 : 90 : 6056·5 : 45° the elevation; so that the range at 45° for this velocity is 6056·5 feet, or 2019 yards. We have already shown that the initial velocity for 25·5 seconds vertical flight is 636·1285 feet per second; we shall now show the velocity for the same time of flight at elevation 45°; it is worked out in the Appendix C. Fired with elevation 45°, if the vertical descent is 8940·9375 feet, the oblique ascent must be $8940{\cdot}9375 \sqrt{2} = 12644{\cdot}4$ feet. We find that the velocity to give an ascent of 12644·4 feet in 25·5 seconds is 733·3 feet per second.

In the Appendix, table D, we give a table showing 32 ranges for this velocity. Any artillerist can now draw the trajectory as described in the last para. on page 378, or he may employ such an instrument as I have now the honour to show, a description of which is given in Appendix F. It is humiliating to think that no book in the English language gives us one service range for elevation, with the initial velocity of the ball. The French are far in advance of us in this respect; their book, the "Aide-Mémoire à l'usage des Officiers d'Artillerie," gives, at p. 431, no less than 30 recorded ranges at 45°, with the initial velocity of the ball for each one. In the Appendix E, will be found the calculation by which our theory would assign an initial velocity of 777·1 feet, or 236·8 metres to the ball, which at 45° ranged 3566·4 yards, or 3261 metres. This velocity the French Aide-Mémoire says was really 239 metres, being only 2·137 metres more than we make it. Our theory, therefore, agrees moderately well with that of the French artillerists, judging from results. How widely it differs from that of Woolwich and Addiscombe, as taught by Hutton, has been shown in section VIII (quod vide). Our greatest want now, is a well-recorded table of times of flight, exceeding 40 or 50 seconds. We have nothing beyond 31 seconds in our books, nor have the French. In the Appendix G, will be found the calculations of the trajectory of a ball which, at 30° elevation, ranged 4850 yards. This ball, at 45° elevation, would range 14,000 feet in 32·79 seconds. According to our theory, if fired vertically upwards, it would not return to the ground until the expiration of 41·58 seconds, its initial velocity being 836·8 feet per second.

The model which I now place before you, will prove to any gentleman, that if he will obtain a true table of ranges for elevation and observed time of flight, he can construct an instrument which shall answer all possible questions on gunnery, and render that science as easy and simple as the first rules of arithmetic. My own instrument may not be true, because I have not got a table of ranges that can be depended upon, and I am denied the means of obtaining one.

TABLE A.

Time of Flight 25·5 Seconds. Initial Velocity, 63613·85 feet per Second.

Seconds of Time.	Vertical Ascent (in feet).		Fall by Gravity, in feet.	Actual Height attained in the whole time.	Space passed through in each ½ second.
	Gradual.	Cumulative.			
0·5	315·9375	315·9375	4·0625	311·875	311·875
1	311·5375	627·475	16·2	611·275	299·4
1·5	307·0625	934·5375	36·3375	898·2	286·925
2	302·5125	1237·05	64·4	1172·65	274·45
2·5	297·8875	1534·9375	100·3125	1434·625	261·975
3	293·1875	1828·125	144·	1684·125	249·5
3·5	288·4125	2116·5375	195·3875	1921·15	237·025
4	283·5625	2400·1	254·4	2145·7	224·55
4·5	278·6375	2678·7375	320·9625	2357·775	212·075
5	273·6375	2952·375	395·	2557·375	199·6
5·5	268·5625	3220·9375	476·4375	2744·5	187·125
6	263·4125	3484·35	565·2	2919·15	174·65
6·5	258·1875	3742·5375	661·2125	3081·325	162·175
7	252·8875	3995·425	764·4	3231·025	149·7
7·5	247·5125	4242·9375	874·6875	3368·25	137·225
8	242·0625	4485·	992·	3493·	124·75
8·5	236·5375	4721·5375	1116·2625	3605·275	112·275
9	230·9375	4952·475	1247·4	3705·075	99·8
9·5	225·2625	5177·7375	1385·3375	3792·4	87·325
10	219·5125	5397·25	1530·	3867·25	74·85
10·5	213·6875	5610·9375	1681·3125	3929·625	62·375
11	207·7875	5818·725	1839·2	3979·525	49·9
11·5	201·8125	6020·5375	2003·5875	4016·95	37·425
12	195·7625	6216·3	2174·4	4041·9	24·95
12·5	189·6375	6405·9375	2351·5625	4054·375	12·475
12·75	92·4984375	6498·4359375	2442·5015625	4055·934375	1·559375
13	90·9390625	6589·375	2535·	4054·375	1·559375
13·5	177·1625	6766·5375	2724·6375	4041·9	12·475
14	170·8125	6937·35	2920·4	4016·95	24·95
14·5	164·3875	7101·7375	3122·2125	3979·525	37·425
15	157·8875	7259·625	3330·	3929·625	49·9
15·5	151·3125	7410·9375	3543·6875	3867·25	62·375
16	144·6625	7555·6	3763·2	3792·4	74·85
16·5	137·9375	7693·5375	3988·4625	3705·075	87·325
17	131·1375	7824·675	4219·4	3605·275	99·8
17·5	124·2625	7948·9375	4455·9375	3493·	112·275
18	117·3125	8066·25	4698·	3368·25	124·75
18·5	110·2875	8176·5375	4945·5125	3231·025	137·225
19	103·1875	8279·725	5198·4	3081·325	149·7
19·5	96·0125	8375·7375	5456·5875	2919·15	162·175
20	88·7625	8464·5	5720·	2744·5	174·65
20·5	81·4375	8545·9375	5988·5625	2557·375	187·125
21	74·0375	8619·975	6262·2	2357·775	199·6
21·5	66·5625	8686·5375	6540·8375	2145·7	212·075
22	59·0125	8745·55	6824·4	1921·15	224·55
22·5	51·3875	8796·9375	7112·8125	1684·125	237·025
23	43·6875	8840·625	7406·	1434·625	249·5
23·5	35·9125	8876·5375	7703·8875	1172·65	261·975
24	28·0625	8904·6	8006·4	898·2	274·45
24·5	20·1375	8924·7375	8313·4625	611·275	286·925
25	12·1375	8936·875	8625·	311·875	299·4
25·5	4·0625	8940·9375	8940·9375	0·0	311·875

LONDON, 16*th April*, 1861.

TABLE B.

To Show the Trajectory for Velocity 636·1385 Feet per Second.

Seconds.	Ascent. Feet.	Descent. Feet.	Range. Yards.	Log. Sine.	Elevation. ° ′ ″
0·5	315·9375	4·0625	105·3	8·1091922	0 44 12·3
1	627·475	16·2	209	8·4119185	1 28 45
1·5	934·5375	36·3375	308	8·58975835	2 13 40
2	1237·05	64·4	411·8	8·7164986	2 59
2·5	1534·9375	100·3125	510·3	8·8152434	3 45
3	1828·125	144	598·	8·8963566	4 31
3·5	2116·5375	195·3875	702·5	8·9652707	5 17 40
4	2400·1	254·4	795·5	9·0252878	6 05
4·5	2678·7375	320·9625	886·5	9·07852407	6 53
5	2952·375	395	973	9·11742555	7 32
5·5	3220·9375	476·4375	1061·8	9·170023642	8 30
6	3484·35	565·2	1146	9·2100804	9 20
6·5	3742·5375	661·2125	1228	9·24712848	10 10
7	3995·425	764·4	1307	9·2817577	11 01
7·5	4242·9375	874·6875	1388	9·314186	11 53
8	4485	992	1458	9·3447493	12 46 40
8·5	4721·5375	1116·2625	1529·2	9·3736828	13 40 30
9	4952·475	1247·4	1597·6	9·40118336	14 35 15
9·5	5177·7375	1385·3375	1656·8	9·427415525	15 31 08
10	5397·25	1530	1725·3	9·45251883	16 28
10·5	5610·9375	1681·3125	1784·3	9·47661306	17 26
11	5818·725	1839·2	1840	9·49980113	18 25
11·5	6020·5375	2003·5875	1892·4	9·522173	19 26
12	6216·3	2174·4	1941	9·5438074	20 28 15
12·5	6405·9375	2351·5625	1986	9·56477385	21 32 12
13	6589·375	2535	2027·4	9·58513377	22 37
13·5	6766·5375	2724·6375	2064·6	9·604942308	23 45
14	6937·35	2920·4	2097·6	9·6242487	24 53 40
14·5	7107·7375	3122·2125	2128·4	9·64273109	26 03 30
15	7259·625	3330	2150·	9·66153000	27 18
15·5	7410·9375	3543·6875	2169·6	9·679582272	28 34
16	7555·6	3763·2	2184	9·6972883	29 52 20
16·5	7693·5375	3988·4625	2193	9·71467936	31 13 33
17	7824·675	4219·4	2196·5	9.73178442	32 38
17·5	7948·9375	4455·9375	2194	9·74862992	34 06
18	8066·25	4698	2186	9·7652413	35 37 20
18·5	8176·5375	4945·5125	2169	9·7818419	37 14 15
19	8279·725	5198·4	2148	9·7978538	38 53 30
19·5	8375·7375	5456·5875	2118	9·8138980	40 39 15
20	8464·5	5720	2080	9·8297947	42 30 45
20·5	8545·9375	5988·5625	2032	9·8455629	44 29
21	8619·975	6262·2	1974	9·8612208	46 35 30
21·5	8686·5375	6540·8375	1905	9·876785	48 51 00
22	8745·55	6824·4	1823	9·8922823	51 17 30
22·5	8796·9375	7112·8125	1725·5	9·9077098	53 57
23	8840·625	7406	1609 3	9·92310075	56 54
23·5	8876·5375	7703·8875	1470·4	9·93830995	60 12 06
24	8904·6	8006·4	1299	9·9538229	64 02 40
24·5	8924·7375	8313·4625	1082	9·96918646	68 40 15
25	8936·875	8625	780·1	9·98457346	74 49 07·8

Time.	Ascent. Feet.	Descent. Feet.	Range. Yds.	Log. Sine.	Elevation. ° ′ ″
20·5	8545·9375	5988·5625	2032·2	9·84556289	44 29 14
6	61·3394	6042·8864	2021·5	9·84870278	44 53 50
7	76·4447	097·4127	2010·4	9·85183835	45 18
8	91·2528	162·1408	....	....	.. .. ..
9	8665·7631	207·0701	....	....	.. .. ..
21	19·975	262·2	1974·	9·8612208	46 35 30

GREAT MALVERN, 10*th August*, 1864.

Appendix C.

A ball, suffered to fall freely from a state of rest, describes a space of 12644·4 feet in the last 25·5 seconds of the time of falling.

To determine the height from which it fell and the velocity acquired by the fall.

1st. The fall for	31·7	seconds is	$31{\cdot}7^2$	$\times$ 13·13 =	13194·2057
	6·2	,,	$6{\cdot}2^2$	$\times$ 15·68 =	602·7392
Differences	25·5	,,	25·5	, 2·55 ,	12591·4665

which is 53·9 feet short.

2nd. The fall for	31·8	,,	$318{\cdot}8^2$	$\times$ 13·12 =	17267·4687
	5·3	,,	$6{\cdot}3^2$	$\times$ 15·67 =	621·9423
	25·5	,,	25·5	, 2·55 ,	12645·5265

which is 1·1266 feet over.

3rd. The fall for	31·79	,,	$31{\cdot}79^2$	$\times$ 13·121 =	13260·1363961
	6·29	,,	$6{\cdot}29^2$	$\times$ 15·671 =	620·0090111
	25·5	,,	25·5	, 2·55 =	12640·127385

which is 4·27 feet short.

4th. The fall for	31·798	$31{\cdot}798^2$	$\times$ 13·1202 =	13266·0022110408
	6·298	$6{\cdot}298^2$	$\times$ 15·6702 =	621·4565765408
	25			12544·4456345

which is only two-thirds of an inch more than the magnitude of A B.

The final velocity represented by a fall of 31·798 seconds' duration is thus found:

the fall in 31·8 seconds, is	$31{\cdot}8^2$	$\times$ 13·12	= 13267·4688
31·798 ,,	$31{\cdot}798^2$	$\times$ 13·1202	= 13266·0022110408
the differences are	0·002 ,	0·0002 ,	1·46658895

which indicates a velocity of 733·2944796 feet, say 733·3 feet per second.

APPENDIX.

Table D.

Initial Velocity 733·3 Feet. Range at 45° = 2980·3125 Yards in 25·5 Seconds.

Secs. of Time.	Graduation of the Ascent. AB.	Graduation of the Descent. BG.	Elevation 90° AB.—BG.	AG = $\frac{}{\sqrt{AB^2 - BG^2}}$	Log. Sine. ∠BAG.	∠BAG. ° ′ ″
1	726·448	16·2	719·248	726·2	8·3483105	1 16 40
2	1438·776	64·4	1374·376	1437·5	8·6508928	2 33 48
3	2136·384	144	1992·384	2131·6	8·8286832	3 52
4	2818·672	254·4	2564·272	2807	8·9554880	5 11
5	3485·04	395	3090·04	3462·5	9·0543893	6 30 30
6	4134·888	565·2	3569·688	4096	9·1357385	7 51 20
7	4767·616	764·4	4003·216	4706	9·2050194	9 13 30
8	5382·624	992	4390·624	5396·5	9·2645176	10 35 40
9	5979·312	1247·4	4731·912	5847·75	9·3193545	12 02 30
10	6557·08	1530	5027·08	6376·33	9·3669809	13 27 45
11	7115·328	1839·2	5276·128	6873·5	9·4124342	14 58 45
12	7653·456	2174·4	5479·056	7338·3	9·4534817	16 30 20
13	8170·864	2535	5635·864	7767·6	9·4917100	18 04 30
14	8666·952	2920·4	5746·552	8159·5	9·5275759	19 41 30
15	9141·12	3330	5811·12	8513	9·5614448	21 21 48
16	9592·768	3763·2	5829·568	8823·6	8·5936133	23 06
17	10021·296	4219·4	5801·896	9089·8	9·6243266	24 54
18	10426·104	4698	5728·104	9307·6	9·6537909	26 47
19	10806·295	5198·4	5608·192	9473·5	9·6822809	28 45 36
20	11162·16	5720	5442·16	9585·2	9·7096478	30 49 30
21	11492·208	6262·2	5230·008	9636·1	9·7363233	33 01 40
22	11796·136	6824·4	4971·736	9621·6	9·7623247	35 21
23	12073·344	7406	4667·344	9535	9·7877561	37 50
24	12323·232	8006·4	4316·832	9368	9·8127127	40 31
25	12545·2	8625	3920·2	9110	9·8373215	43 26 30
26	12738·648	9261·2	3477·448	8746·5	9·8615440	46 38 15
27	12902·976	9914·4	2988·576	8258	9·8855765	50 12 30
28	13037·584	10584	2453·584	7613	9·9094526	54 16 30
29	13141·872	11269·4	1872·472	6761	9·9332435	59 02 30
30	13215·24	11970	1245·24	5600	9·9570191	64 55 30
31	13257·088	12685·2	571·888	3851·7	9·980849	73 06 30
31·8	13267·2688	13267·4688	0·0		10·0000000	90

Appendix E.

The French Aide-Mémoire gives a range at 45° elevation of 3261 metres, with initial velocity 239ᵐ.

1. This range is 10699·341 English feet at 45°, the vertical descent, or fall by gravity is therefore also 10699·341, whence we deduce the time of flight, 28·17 seconds, for $28{\cdot}17^2 \times 13{\cdot}483 = 10699{\cdot}4198187$ feet.

2. The oblique ascent in that time is $10699{\cdot}34\sqrt{2}$ or $15131{\cdot}15$ and the mean velocity of this ascent is $\dfrac{15131{\cdot}15}{28{\cdot}17} = \dfrac{R}{t} = 537$ feet.

3. The time in which a falling body acquires a velocity of 537 feet is 20·2 seconds, if we add to this one-half of the time of flight, $20{\cdot}2 + 14{\cdot}085 = 34{\cdot}285$ we shall have an approximation to the possible time of flight of this ball's initial velocity, therefore an approximate indication of the initial velocity.

4. More exactly we find that the fall by gravity
in 35·32 seconds is $35{\cdot}32^2 \times 12{\cdot}768 = 15928{\cdot}1106432$ and
in $\underline{7{\cdot}15}$ $\qquad \underline{7{\cdot}15^2} \times \underline{15{\cdot}585} = \underline{796{\cdot}7430625}$ so that
in 28·17 we have 28·17, $\quad 2{\cdot}817 \quad 15131{\cdot}3675807$ almost exactly the magnitude and duration of the oblique ascent.

5. The velocity which a ball acquires by a fall of 35·32 seconds is easily found—

From $35{\cdot}32^2 \times 12{\cdot}768 = 15928{\cdot}1106432$
Take $\underline{35{\cdot}31^2} \times \underline{12{\cdot}769} = \underline{15920{\cdot}3394009}$, the differences
$0{\cdot}01$, $\quad 0{\cdot}001$, and $\quad 7{\cdot}7712423$ indicate a velocity of 777·12423 feet which is 236·86318 metres, differing from the French 239 metres by $2^{m}{\cdot}13682$.

Appendix F.

Description of an Instrument Constructed to Show the Trajectory of a Ball from given Elevation and Range, together with its Initial Velocity and Force of Striking.

The instrument consists of three straight bars and a set of metal rods; the three bars form a right-angled triangle, upon the hypothenuse of which we hang the metal rods to denote the fall by gravity in successive seconds, the trajectory is then visible; the initial velocity is printed on the hypothenuse, and the final velocity, multiplied by the weight of the ball, is the force of the stroke.

The three straight bars represent:—

I. The oblique ascent in the time of flight, *t*.
II. The vertical descent in the time of flight, *t*.
III. The horizontal range resulting from the two simultaneous motions of ascent and descent.

The two bars which represent the ascent and the descent are joined by a hinge, forming the apex of the right-angled triangle; these two bars are graduated exactly alike. Upon the vertical bar the graduation represents the fall by gravity, as modified by the resistance of the atmosphere; upon the front of the vertical bar are printed the figures 1, 2, 3, and so onwards to denote the time; and on the side of it, the figures 16·1, 64·4, 144, and so on to denote the fall by gravity. Upon the oblique bar is printed the velocity which a ball would acquire by falling vertically through a space equal to the distance from the apex of the triangle to each point of the graduation. The horizontal

bar is graduated by merely marking off equal spaces to represent successively 100, 200, 300 yards' range. At one end of the horizontal bar is a pentagraph joint, fixed; through the side tube of this passes the bar of oblique ascent; this side tube represents the gun. Upon the horizontal bar is a moveable pentagraph joint; through the side tube of this passes the bar of vertical descent.

We now proceed to show how to use the instrument. Set the oblique bar to the required angle with the horizontal bar, and run it out until the vertical bar intersects the horizontal bar at the required distance, the given range, you have now the triangle, within which is to be inscribed the trajectory. Read the time of flight upon the vertical bar, and select from the metal rods all those marked for less time than this time of flight, and one more, upon which you mark the exact length of the vertical bar. Upon the third mark of graduation of the oblique bar, hang the metal rod marked 3, upon the next that marked 4, and so on, till all are hanging from the oblique bar, when it will be seen that the last few hang below the horizontal bar, and the last comes short of the given range. Now run out the bar of oblique ascent one step of the graduation marked upon it, transferring each of the pendulums one step in succession, keeping the elevation the same; move the vertical bar further from the gun, increasing its length at the same time; this bar ceases now to be of any use except as a pillar to support the bar of oblique ascent with all its pendulums. If the longest pendulum still shows below the horizontal bar, the oblique ascent must again be run out, and all the pendulums shifted, till the mark upon the longest pendulum as stated above exactly coincides with the given range of the ball, then the trajectory is shown, and the initial velocity read off.

APPENDIX G. SHOEBURYNESS, NOVEMBER 24th, 1854.

10-inch Howitzer of 125 cwt. Shot 140 lbs. Charge 16 lbs., $\frac{16}{140} = 0{\cdot}1142857142857{\cdot}$ Elevation 30°. Range 4,850 yards = 14,550 feet. Oblique Ascent 16,800·8 feet. Vertical Descent 8400·4. Time 24·64. Initial Velocity, 836·8.

Seconds.	Oblique Ascent, Feet.				Simultaneous Vertical. Descent	Range in Yards.	Elevation.
	Cumulative.	Gradual.	Differences.				
					Feet.		° ′ ″
1	832·91308	832·91308	8·252		16·2	277·6	1 05 20
2	1657·57416	24·66108	852		64·4	552	2 13 40
3	2473·38324	15·809	9·4		144	823	3 20 15
4	3279·74032	06·357	10·0		254·4	1090	4 27
5	4076·04540	796·305	6		395	1352	5 33 33
6	4861·69848	85·653	2		565·2	1610	6 40 36
7	5636·09956	74·401	8		764·4	1861	7 47 40
8	6398·64864	62·549	4		992	2107	8 55 07
9	7148·74572	50·097	13·0		1247·4	2346	10 03
10	7885·79080	37·045	6		1530	2579	11 11 11
11	8609·18388	23·393	2		1839·2	2803	12 20 07
12	9318·32496	09·141	8		2174·4	3020	13 29 40
13	10012·61404	694·289	4		2535	3229	14 39 58
14	10691·45112	78·837	16·0		2920·4	3403	15 57 45
15	11354·23620	62·785	6		3330	3618	17 03 15
16	12000·36928	46·133	2		3763·2	3791	18 16 30
17	12629·25036	28·881	8		4219·4	3968	19 31 02
18	13240·27944	11·029	4		4698	4126	20 47
19	13832·85652	592·577	19.0		5198·4	272	22 04 26
20	14406·38160	73·525	6		5720	407	23 23 42
21	14960·25468	53·873	2	0.6	6262·2	529	24 44 40
22	15493·87576	33·621	8		6824·4	637	26 08
23	16006·64484	12·769	4		7406	730	27 33 40
24	497·96192	491·317	22.0		8006·4	807	29 01 54
25	967·227	69·265	6		8625	872	30 33 10
26	17413·84008	46·613	2		9261·2	915	32 07 40
27	837·20116	23·361	8		9914·4	43	33 46 04
28	18236·71024	399·509	4		10584	50	35 28 31
29	611·76732	75·057	25·0		11269·4	37	37 15 51
30	961 77240	50·005	6		11970	03	39 08 40
31	19286·12548	24.353	2		12685·2	857	40 55 48
32	584·22656	298·101	8		13414·4	759	43 13 30
33	855·47564	71·249	4		14157	640	45 28 45
34	20099·27272	43·797	28·0		14912·4	492	47 53 46
35	315·01780	15·745	6		15680	174	50 31 20
36	502·11088	187·093	2		16459·2	075	53 24
37	659·95196	157·841	8		17249·4	3790	56 36 30
38	787·94104	127·989	4		18050	3437	60 15 45
39	885·47812	97·537	31·0		18860·4	2990	64 33 40
40	951·96320	66·485	6		19680	2396	69 56
41	986·79628	34·833	32·252		20508·2	1485	77 44 30
41·58	20992·26009	5·46381			20992·26	0·	90

Demonstration.

AB = 16800·8
BG = 8400·4 therefore t = 24·64 for $24{\cdot}64^2 \times 13{\cdot}836 = 8400{\cdot}2451456$ ft.
AG = 14550

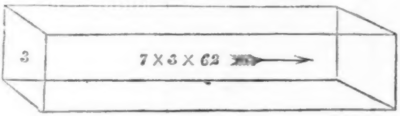
$$\begin{array}{lllll} \text{Then} & 41{\cdot}58^2 \times 12{\cdot}142 & = & 20992{\cdot}2600888 & \\ & 16{\cdot}94^2 \times 14{\cdot}606 & = & 4191{\cdot}3903416 & \\ \hline & 24{\cdot}64 \quad 2{\cdot}464 & & 16800{\cdot}8697472 & = AB. \\ \text{And} & 41{\cdot}58^2 \times 12{\cdot}142 & = & 20992{\cdot}2600888 & \\ & 41{\cdot}57^2 \times 12{\cdot}143 & = & 20983{\cdot}8920807 & \\ \hline & 0{\cdot}01 \times 0{\cdot}001 & & 8{\cdot}3680081 & \text{shows } V = 836{\cdot}8 \end{array}$$

Mr. OLIVER BYRNE: When great minds conspire to perpetuate a fallacy, it has always been a difficult matter to clear that fallacy away. I know of no subject capable of being submitted to mathematical investigation that has received a greater amount of fallacious treatment, and that too, by great minds, than the motion of projectiles. Initial velocities have been little more than guessed at, the resistance of the air overrated, and the force of gravity mis-stated. The system introduced by Gen. Anstruther, which is practical, and easily applied, must give correct results within the range of his experiments, without offering any special theory about initial velocities, the resistance of the air, or the force of gravity. Indeed in his system are collected all those elements. Let us examine the theories put forward with respect to the resistance of the atmosphere to the motion of a ball passing through it. The resistance of a fluid to the motion of a body is said to vary as the square of the velocity; the hypothesis

upon which this law rests may be thus considered; the fluid displaced must have the same motion given to it as that of the moving body, hence on this supposition, the units of work destroyed by the fluid will be equal to the accumulated work in the fluid.

Fig. 1.

Velocity = 7 feet a second.



For example, let the cross-section of the body perpendicular to the direction in which the body moves = 3 sq. ft. the weight of a cubic foot of the fluid = 62 lbs., and the velocity of the body 7 ft. a second.

The weight of the fluid moved at a velocity of 7 ft. a second = 7 × 3 × 62 lbs.

The units of work expended in the displacement will be—

$$\frac{7^2 \times 7 \times 3 \times 62}{2\,g}$$

In which g is put = $32\frac{1}{6}$; $32\frac{1}{8}$; 32; &c.; and is said to vary inversely, as the square of the distance from the centre of the earth.

Then the body in moving through 7 ft. destroys—

$$7 \times \frac{7^2 \times 3 \times 62}{64} \text{ units of work.}$$

If T be the resistance of the fluid in pounds, the units of work destroyed will also be represented by T × 7;

$$\therefore\ T \times 7 = 7 \times \frac{7^2 \times 3 \times 62}{64}$$

$$\text{or } T = \frac{7^2 \times 3 \times 62}{64}$$

Hence it is concluded that the resistance increases with the square of the velocity, as well as with the area of the cross section of the body presented to the fluid. It is easily perceived, especially with high velocities, that this law is not strictly true, and very far from the truth when the motion takes place in air. It has been found from experiments on railways, that the resistance of the atmosphere to the motion of the train, depends chiefly on the length of the train, and not upon the frontage of the carriages. The resistance resembles more that of friction than the moving of a long paralleloped of the fluid in which the body moves.

Taking this latter view of the motion of a ball through the atmosphere from one given point to another, the units of work will always be the same, whatever may be the form of the curve described.

Let W, Fig. 2, be a body moved through the air, then by the resolution of pressures, the pressure of W, perpendicular to the tangent = W Cos a.

$$\therefore \text{ The resistance of friction} = f\,\text{W Cos}\,a,$$

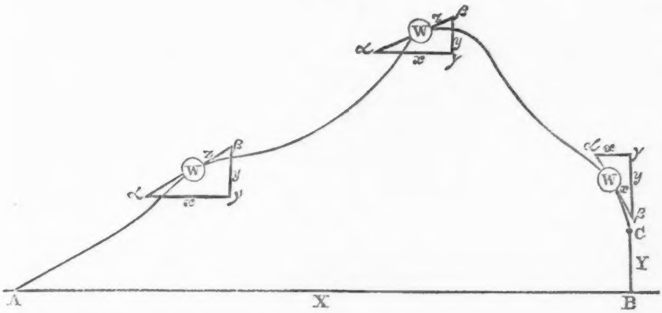
putting f for the co-efficient of the friction of the air on the ball. Hence the total work on the plane $a\,\beta = z f$ W Cos a + Wy; but $z \cos a = x$,

$$\therefore \text{ The work on each plane} = f\text{W}\,x + \text{W}y.$$

This expression being independent of the inclination of the plane. It points out the work employed to move the body over the horizontal distance $a\gamma$, added to the work due to the gravity in elevating the body the vertical space $\beta\gamma$. Since a curve may be supposed made up of an infinite number of straight lines, therefore the work upon the whole curve will be equal to the work done upon the horizontal projection A B, added to the work done in opposition to gravity in raising the body from B to C, no matter what form be given to the curve A W W W C. This demonstration shows

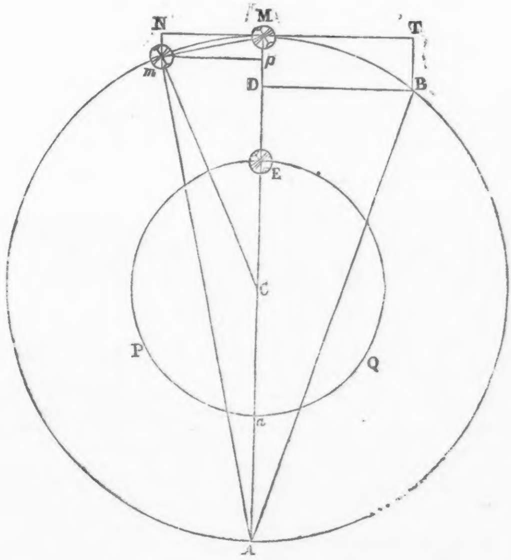
that the way in which General Anstruther has treated the resistance of the air to be the most rational yet proposed. In the next place let us examine the manner in which the value of g, representing the force of gravity, has been estimated.

FIG. 2.



Let r = C M = radius, Fig. 3.; v = the uniform velocity of M on the curve: t = the time employed in moving from M to m, or in falling from M to p. If f be considered constant during a short space of time

FIG. 3.



$$f\,dt = dv$$

$$\therefore f t = v = \frac{ds}{dt}$$

$$\therefore s = \frac{f t^2}{2} = Nm = Mp.$$

$mM = vt =$ uniform velocity × time.

Again suppose the time so short that the arc is equal to the chord, or arc m M = chord m M.

Then $Mp \times MA = (\text{chord } Mm)^2 = (\text{arc } Mm)^2 = (vt)^2$;

$$\text{but, } Mp = \frac{f t^2}{2} \text{ and } MA = 2r,$$

$$\therefore Mp \times MA = \frac{f t^2}{2} \times 2r = v^2 t^2$$

$$\therefore f = \frac{v^2}{r}; \text{ (A).}$$

If T be the time of an entire revolution, then

$$Tv = 2\pi r \quad \therefore v^2 = \frac{4\pi^2 r^2}{T^2}$$

$$\text{and } f = \frac{4\pi^2 r}{T^2}; \text{ (B).}$$

Let another body E, Fig. 3, describe the circumference of a circle E P Q in the time T_1; and let F represent the accelerating force of gravity at E. Put R = E C, then, from (B)

$$F = \frac{4\pi^2 R}{T_1^2}$$

$$\therefore f : F :: \frac{r}{T^2} : \frac{R}{T_1^2} : \text{ (C).}$$

Now the third law established by the experiments of John Kepler shows that the squares of the times are as the cubes of the distances from the centre C; hence if we put r^3 for T^2, and R^3 for T_1^2, then (C) becomes

$$f : F :: \frac{1}{r^2} : \frac{1}{R^2} \text{ (D).}$$

and thus it is shown by the experiments of Kepler, that the force of gravity varies inversely as the squares of the distances. Sir Isaac Newton had little to discover in this matter when Kepler's laws are admitted. The experiments at General Anstruther's command are as accurate as those upon which the law indicated by (D) is founded. The influence of gravity on the motion of the moon round the earth, or of the earth round the sun, is then compared with the falling of a heavy body near the earth's surface, and near the earth's surface f is represented by g, which is said to be found by experiments. Astronomers apply a variety of corrections to uphold (D), and the cooked up value they have given to g. When g is trimmed up to suit the motions of the heavenly bodies, it is out of gear to apply it to the falling of heavy bodies in air near the earth's surface. In changing the value of g, General Anstruther is right, for his system corrects the constant quantities, and secures correct results within the range of his limiting experiments.

To find whether the resistance of the air or any other fluid medium is proportional to the square of the velocity (V) or not, and also to find whether the value usually given to (g), the force of gravity near the surface of the earth is under or over-estimated.

Generally g is put $= 31\frac{1}{6}$; $32\frac{1}{3}$; 32, &c.

Let v^2 multiplied by some constant coefficient express the retarding force; and to simplify the investigation put this coefficient under the form n^2g.

Then the retarding force will be expressed by—

$$g - gn^2v^2 \; ; \; (\text{I}).$$

In this investigation s is put for the space passed over in the time t.

In general terms if F be any accelerating force, U the velocity, S the space, and T the time, the relations between these quantities are found from the two equations—

$$U = \frac{dS}{dT} \text{ and } F = \frac{dU}{dT} \; : \; (\text{II}).$$

When T is eliminated from these equations, then

$$UdU = FdS \; : \; (\text{III}).$$

Again eliminate U, then we have

$$FdT = \frac{d^2S}{dT} \; : \; (\text{IV}).$$

Then from (I) substitute $g\,(1 - n^2v^2)$ for F in (II), then,

$$gdt = \frac{dv}{1 - n^2v^2} \; : \; (\text{V}).$$

$$\text{From (III)}, \; gds = \frac{vdv}{1 - n^2v^2} \; : \; (\text{VI}).$$

When the equations (V) and (VI) are integrated and corrected, on the supposition that when $t = o$; $v = o$ and $s = o$; the resulting equations will be

$$v = \frac{1}{n}\,\frac{\epsilon^{2gnt} - 1}{\epsilon^{2gnt} + 1} \text{ and } s = \frac{1}{2gn^2}\log.\frac{1}{1 - n^2v^2}$$

Eliminate v and equation (VII) is obtained

$$s = \frac{1}{n^2g}\log\frac{1}{2}\left\{\epsilon^{ngt} + \frac{1}{\epsilon^{ngt}}\right\} \quad (\text{VII}).$$

The reduction may be effected as follows :—

$$v^2 = \frac{1}{n^2}\,\frac{(\epsilon^{2ngt} - 1)^2}{(\epsilon^{2ngt} + 1)^2} \quad \therefore \quad n^2v^2 = \frac{(\epsilon^{ngt} - 1)^2}{(\epsilon^{ngt} + 1)^2}$$

$$1 - n^2v^2 = \frac{4\,\epsilon^{2ngt}}{(\epsilon^{2ngt} + 1)^2}$$

$$\text{Then } \frac{1}{1 - n^2v^2} = \frac{(\epsilon^{2ngt} + 1)^2}{4\,\epsilon^{2ngt}} = \left(\frac{1}{2}\right)^2\left(\frac{\epsilon^{2ngt} + 1}{\epsilon^{ngt}}\right)^2$$

$$= \left\{\frac{1}{2}\,\frac{\epsilon^{2ngt} + 1}{\epsilon^{ngt}}\right\}^2$$

$$= \left\{\frac{1}{2}\left(\epsilon^{ngt} + \frac{1}{\epsilon^{ngt}}\right)\right\}^2$$

$$\therefore s = \frac{1}{2n^2g}\log\frac{1}{1 - n^2v^2} = \frac{1}{n^2g}\log\frac{1}{2}\left(\epsilon^{ngt} + \frac{1}{\epsilon^{ngt}}\right).$$

(VII) may be put under the form

$$2\epsilon^{sgn^2} = \epsilon^{gnt} + \frac{1}{\epsilon^{ngt}} \quad (\text{VIII}).$$

Now from (VIII) the values of n and g may be found by dropping cannon shot from a balloon, at different known heights, the time occupied in falling being measured. Two different values of s and two corresponding values of t being thus

determined (VIII) presents two independent equations, from which n and g may be eliminated by the dual method of solving equations. I have but little doubt that the liberty taken by the General to change the reputed force of gravity near the surface of the earth, to meet the practical necessity, will be warranted when the value of g and the resistance of the atmosphere are independently and accurately determined. The force of gravity is pulled in all directions by astronomers, to make it fit the motions of the heavenly bodies, yet after all the corrections and allowances are made, the moon and asteroids will not obey. The practical results given by the system of General Anstruther also show that it is right to change the initial velocities previously conjectured, for it is easily demonstrated that the initial velocities given, both by the ballistic pendulum and the pendulum of Navez, are erroneous. These instruments may be employed to indicate any conjectured initial velocity, for the time incorporated in the calculation is made to depend on a body very much restrained, falling in air a few inches. To say the least of the process, it is very ridiculous; the results may be corrected until the time anticipated is obtained. The value of g in or out of air is unknown, and yet it is made to tell all about the pendulum, and in return the pendulum is made to tell all about g. The General points out the errors of other systems in bold relief, and arrives at practical results within the range of his guiding experiments, without assuming initial velocity, a particular value for g, or including any wild theory about the wonderful resistance of the atmosphere to cover shortcomings.

Captain HEATH, R.N., C.B.: It is not easy to discuss a lecture of this nature at a moment's notice, but I should like to put one or two test questions to the General. 1st. Do I understand you (addressing the General) to say, that if a shot weighing 3 lbs., and another weighing 100 lbs., are discharged in the air at the same elevation, and with charges such that they shall both have the same range, they must then, according to your theory, have started with the same initial velocity?

General ANSTRUTHER: Yes, provided they are spherical shot.

Captain HEATH: Secondly, do I also understand you to uphold that if those same shot, viz., one of 3 lbs., and one of 100 lbs., are dropped simultaneously from a balloon two miles high, they will both, falling through the air, reach the ground at the same moment?

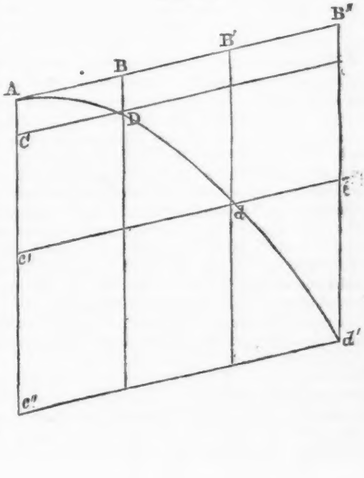
General ANSTRUTHER: Yes.

Captain HEATH: Then I have no more questions to ask, the answers you have given clearly prove to my mind that your theory is erroneous. With respect to the disbelief avowed by the gentleman who has just made remarks on the paper, in the correctness of Major Navez's instrument for measuring initial velocities, I wish to point out to him that if he will take the observed initial velocities recorded in the book in his hand, and multiply them by 2 or 3, he will find the results a little larger than the observed ranges for a two or three seconds time of flight, which is what those who believe in "resistance of the air" would expect, and this is, I think, a rough and ready proof of the correctness of the observed initial velocities.

J. REDDIE, Esq.: Mr. Chairman, as an old member of this Institution, and although a civilian, I beg leave to make a few observations on the interesting and important subject under discussion; it being one to which I have given considerable attention. I regret that I have not been able completely to master General Anstruther's system, and do not understand upon what principle the vertical parallels in his diagrams are made to vary in their relative distances, and gradually to decrease from the beginning to the end of the trajectory. It is of course plain, that if these parallels were equidistant throughout, the construction would resolve itself into a parabola; than which—though it happens to be the theoretical path of a projectile *in vacuo*—nothing can be further from the real path of a projectile in the air. But I am told that these parallels are diminished in distance, according to a principle, though to me they appeared to be so, only by a kind of rule of thumb. Of one thing, however, I feel perfectly certain, namely, that the deviation of projectiles so immensely from the theoretical parabolic path, is not entirely—or, indeed, to any great extent—due to the resistance of the air. This deviation, I may observe, is so very great, that even Dr. Whewell, as a Cambridge mathematician (implicitly accepting the theoretical accuracy of the parabolic trajectory *in vacuo*), admits that the old trajectories of Robins

and other practical gunners, are far more nearly accurate, according to our actua experience whenever a ball is fired. It is, in fact, only when balls are fired at very slight elevations that their trajectory has the least resemblance to a parabolic curve; and from that fact I argue,—1st. That it is not "the resistance of the air" that throws out the theory; for the air is equally present when trajectories are low as when they are high; and consequently, 2nd, that the parabolic theory is at fault, because we don't know the real value of "g," or the true accelerative force of a falling body. I regret that my friend Mr. Byrne has not been able to give us a corrected value of g, or a true theory of the ratio of the accelerative force with which a body falls; though he has given us a formula by which to discover this ratio, when furnished with a few facts as to the time of falling from a great height,—facts which there is now no excuse for our not ascertaining. Those who adhere to the traditional theory of the air's great resistance, ought to tell us why the air should, as it were, conspire (as upon their theory it does) against a body moving onwards, and not equally against its downward course, or in other directions? If "the terminal velocity of a falling body cannot exceed 419 feet per second" (as in the quotation in General Anstruther's paper), how could the initial velocity of a ball when fired, exceed that rate? But, again, we know that there is a greater curvature towards the earth in the latter part of a projectile's flight than at the beginning; from which it may be inferred that this bending towards the earth is caused by gravity having very much more influence than the current theory gives, and the air very much less. Instead of the ball having it descent retarded, it is very clear that its downward course must rather be hastened, towards the end of its path, or its trajectory would take a different form. As the air will act equally against the ball in rising and in falling, its chief influence must be against the onward path of a body when fired obliquely; and were resistance relatively less when the velocity is greater (contrary to the current notions), that might account to some extent for the greater curvature downwards, as the onward velocity of the body becomes reduced. But, I must say, that that alone would not account for the suddenness and greatness of such curvature. That, I feel certain, will be found to be due to the fact, that the accelerative force of gravity, now said to be equal to 32 feet per second, has been greatly underestimated. This ratio may be approximately true for a fall of one or two seconds (and hence the agreement of the theory with the actual flight of projectiles at slight elevations); but it cannot be the true ratio of the effect of the constant force of gravity pressing downwards, after a body begins to descend. I may observe that I think there has been some misapprehension as to current views regarding the course of a projectile. Granting the ratio of the fall of a body in equal times to be, as 1, 3, 5, 7, &c., or as the squares of the whole times, 1, 4, 9, 16, &c., there is no error in the usual mode of constructing the parabolic trajectory, as *in vacuo*. This is usually done by representing the projectile force, according to the first law of motion, as equal in equal times, or as the ordinates A B B′ B″ in figure 1, annexed, and the force of gravity as the abscissæ A C c' c'', as equal to the squares of the times. These two forces combined give the parabola A D d d'.

FIG. 1.

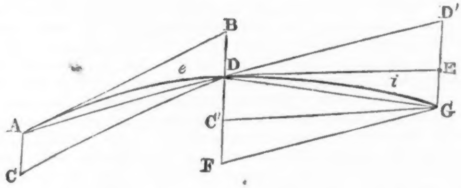


But there is a fallacy in this mode of treating the two forces as

if they retained their original directions; which I beg leave to point out. The gravity which is a constant force, of course continues always to impress new forces in one direction downwards; but the original projectile velocity becomes changed gradually, from the first moment, under the influence of gravity; and, by the second law of motion, its tendency is never after the first moment in the direction of its original motion. A truer demonstration of the theoretical path of a projectile *in vacuo*, taking the current value of g, would therefore be this:—

Let A B (Fig. 2) be the original projectile velocity of a body which would fall from rest A C in the time it would describe A B by its force of projection alone. Then, if gravity acted impulsively, by the forces A B, A C, the body would describe A D, and, if gravity ceased at D, would go on and next describe D D′ in an equal time. If, however, gravity is again supposed to act at D, we must now suppose (according to the current methods) that it is represented by D F = 2 A C; and if we combine D D′ with D F, by these two forces the body would next describe D G, the diagonal of the parallelogram D D′F G; and a curve cutting the points A D G will be a parabola. But that, I say, is a faulty demonstration, based upon the false suppositions, that gravity acts impulsively; which we know to be impossible. Instead, therefore, of supposing that the projectile velocity A B is combined with the *impulsive* force A C, let the gravity represented by A C act naturally, and the body will then describe, not A D,

FIG. 2.



but A *e* D, in the first time; and from the point D, were gravity to cease, it would go on in the direction D E (tangent to curve A *e* D) and not in the direction D D′. If at the point D, then, we suppose gravity continues to act, we must represent it by D C′ = A C (for gravity *ex hypothesi* is a constant force, impressing equal forces in equal times); and by D E, D C′, the body will next describe D *i* G; and the curve A *e* D *i* G will be a parabola. It will be observed that in this demonstration the force of gravity is taken as equal in the two times, and not twice as great in the next second as it was in the first. It would occupy too much time to give a full *rationale* of this now, and all its results; but no one will venture to deny that D E and not D D′ represents the body's tendency after describing A *e* D. If so, it is clear that gravity must be taken as D C′ = A C only, at the point D, or the parabolic trajectory will be thrown out. For those who rest upon authority in such matters, I may state that I have Professor Whewell's admission, so far back as 1846, that D E is the proper line to represent the projectile velocity from the point D, though in what are called "authorised works" on dynamics, this demonstration has never been given. It was first put forward publicly in 1862, in a small work, "Vis Inertiæ Victa, or Fallacies affecting Science," a copy of which is in the library of this Institution, and to which I would beg to refer (Sec. vi.) for further arguments and illustrations.

Rear-Admiral E. P. HALSTED: Would General Anstruther inform us whether his system would require modification, if used for rifled projectiles?

General ANSTRUTHER: I have been unable to procure any data of rifled cannon firing whereby to test my system.

The CHAIRMAN: You will allow me to return your thanks to General Anstruther for his important paper; for though his views have been questioned, assuming the data given him to be correct, unless our received trigonometry be at fault, his conclusions are undeniable; and he, and Messrs. Byrne and Reddie, have shown the necessity for determining the true value of gravity.

NOTES ON THE COMPARATIVE PENETRATION OF SHOT AND SHELL FROM RIFLED AND SMOOTH-BORE ORDNANCE INTO NATURAL AND MADE EARTHWORKS.

A Paper contributed by Captain W. S. Boileau, R.E.

The chief object of these experiments, as originally arranged by the Ordnance Select Committee, under whose directions they were eventually carried out, in August and September, 1863, was to test fully the explosive powers of the pillar and other fuzes that had been brought to their notice, as peculiarly adapted, from their sensitive nature, for use with shells fired from rifled guns into earth; it was, however, found convenient to extend these experiments, and the following programme was adopted:—

1st Experiment.—To ascertain the penetration of projectiles, solid shot, and blind shell, fired from rifled and smooth bored guns into earth at a range of 1,060 yards.

2nd Experiment.—To ascertain whether the pillar fuze (for rifle shells only) would explode shells fired into earth.

This experiment also embraced the testing of the following fuzes, viz.:—

1. A more sensitive form of pillar fuze.
2. Field service percussion fuze for rifle shells only, enlarged to screw into the Moorsom-gauge fuze hole.
3. Pettman's land service fuze for spherical shells only.
4. Pettman's sea service fuze, adapted to rifle shells.

3rd Experiment.—Breaching an earthwork.

The site selected was a portion of the coast-land about ¾ mile S.W. of the town of Newhaven, Sussex, the natural features of which rendered it peculiarly advantageous. A portion of the crest of the hill, called Castle Hill, presenting a moderately sloping front and forming naturally an admirable butt, was marked off into three targets, the contours shown at every 39 feet by means of furrows filled with chalk stones, and was termed the "*natural butt.*" At the base of this mound a simple parapet, 72 feet in length, with a relief of 12 feet, measuring 25 feet on the superior slope, and having a total width at its base of 39 feet, had been thrown up, and was designated *No. 1 earthwork.* A second work, similar to the foregoing, was constructed after the commencement of the experiments, having its crest line in the prolongation of No. 1, but with a clear space between the two works, and a cutting in rear about 30 feet in width and called *No. 2 earthwork.*

The battery, which consisted of the following guns, viz.:—

Rifled Guns.		Smooth-bored Guns.
1—110-pounder.	Armstrong.	1—68-pounder.
1—70-pounder	do.	1—32-pounder.
1—40-pounder	do.	1—10-inch gun.
1—20-pounder	do.	1—8-inch gun.
1—12-pounder	do.	

was situated on the crest of the hill known as Windmill Hill, distant 1,060 yards from the butts, at which range all the experiments were conducted.

Plate No. 37 shows the relative position of the battery and butts with the features of the intervening space.

Plate No. 38 is a plan with sections of No. 1 earthwork, showing the penetration of each description of projectile.

Plate No. 39 affords similar information with regard to the natural butt.

Plate No. 40 is a plan with sections of No. 2 earthwork, showing the breach.

Plate No. 41 gives sketches of a few of the craters formed by rifle and spherical shells.

Table No. 1 gives the penetration in feet and inches of every projectile dug out of the natural and artificial butts, and the nature of soil in which they were found.

Table No. 2 gives the mean penetration in feet and inches for each description of projectile in each nature of soil, with the results abstracted for greater facility of reading.

Table No. 3 gives the results of the experiment for testing the different descriptions of fuzes.

Before proceeding to explain the details of each experiment, and to notice briefly a few of the most important facts to be gathered from the general results, it may be well to give a short description of the soil met with in the natural and artificial butts; that of the former was of very hard gravel, with veins of *stiff* clay, and a flinty conglomerate, better described, perhaps, by the term "*natural concrete*" than any other I know of; the soil of the butt was throughout of the hardest possible nature, offering a greater resistance to penetration than most soils that would, under ordinary circumstances, be met with; this is a fact worthy of note, and should be borne in mind when comparing the penetrations into natural and made earth. The artificial butts or earthworks were, in both instances, constructed of a very compact loam, almost equal in consistency to clay, mixed here and there with white and red sand; the natural soil on which these butts rested, and which, from its unevenness, cropped up into the body of the works in one or two places, was of stiff clay.

In order to obtain fair results from which to strike averages for the 1st experiment, viz.:—the penetration of elongated and spherical pro-

jectiles, solid shot, and blind shell,* into made and natural earthworks —it was determined that the fire from each gun should be kept up with full service charges until five good hits were obtained, and in accomplishing this, 158 rounds were fired at No. 1 earthwork, and 87 rounds at the natural butt; the results of which form the subject of Tables Nos. 1 and 2. From them we find that the greatest amount of penetration both in the artificial and natural butts was obtained by the 110-pounder Armstrong with the usual service charge of 12 lbs., being respectively 21 feet 3 inches and 10 feet 3 inches for solid shot, and 16 feet 8 inches and 10 feet 5 inches for blind shell, whilst the next in merit is the 68-pounder smooth-bore with the usual service charge of 16 lbs., the penetrations from which are respectively 19 feet 11 inches and 9 feet 3 inches for solid shot, and 14 feet 10 inches and 7 feet 6 inches for blind shell; the amount of penetration obtained by the other natures was such as might have been expected from the foregoing, decreasing in each instance in proportion to the difference of calibre, with the exception of the 70-pounder Armstrong, which did not give such satisfactory results as were anticipated, and proved inferior to the 40-pounder Armstrong. This strange circumstance is, however, in a great measure accounted for by the fact, that the solid shot of the 70-pounder were all fired with *hollow* conoidal heads, which, no doubt, broke off at impact,† thus leaving a flat surface opposed to penetration, whereas the solid shot for all other calibres of Armstrong guns were cast with solid heads.

The effect produced upon the parapet (No. 1 earthwork) by the 158 rounds fired at it, was trifling, the upper crust of the superior and exterior slopes was, of course, somewhat disturbed, but not a single shot had passed through the parapet, which virtually remained as good as ever, and still afforded perfect shelter; in fact, the interior slope, with the exception of one or two slight indentations at the crest caused by ricochets, remained intact.

The extraordinary accuracy of aim of the rifled guns was throughout most apparent, and their vast superiority in this point over the smooth bores fully established. The position of the elongated projectiles on being dug out is worthy of note, and I have endeavoured to show their positions in table No. 2 by means of rough diagram representations, from which it will be seen that the general tendency was for the shot or shell after impact to deflect to the right, or in the direction of the twist it received on leaving the muzzle; it was also clearly proved that projectiles fired from rifled guns do not continue, after the primary impact, to penetrate point first, for all were found with their points more or less deflected from the direction of the line of fire, and in some instances the shot had turned completely round, and were found with their noses pointing towards the battery.

The next experiment was for the purpose of testing the pillar and other fuzes enumerated at the commencement of this paper: the results,‡

* The blind shell were merely the common shells fired by each description of gun, filled with sand and plugged.—W. S. B.

† All the 70-pounder solid shot were found *minus* their heads!—W. S. B.

‡ For particulars, *vide* Table No. 3.—W. S. B.

on the whole, were unsatisfactory, and showed that the action of the service percussion fuzes when fired into earth, cannot be depended upon. The unusual number of premature bursts that occurred when firing live shell from the 110-pounder Armstrong with the pillar fuze and full service charge, led to a special inquiry as to the cause. With this object in view, a wooden disc or sabot was placed at the base of the projectile; on other occasions a vacant space was left between the cartridge* and the projectile, and on others between the vent-piece and the end of the cartridge; none of these precautions, however, had the desired effect, and it was only when the charge of the gun was reduced to 9 lbs. that the premature bursts disappeared. As the accident was confined to the pillar fuzes containing amorphous phosphorus (those with the Moorsom composition answering admirably), it was inferred that the fault lay with the composition, but I think it not unreasonable to suppose, that the failures were attributable in some degree to the construction of the fuze, which from the concussion attending so large an amount of powder as 12 lbs. may have become prematurely set up, and this idea seems to gain weight when it is remembered that the premature bursts did not occur with any of the lesser calibres, and even disappeared with the 110-pounder when the charge was reduced.

The testing of the fuzes afforded opportunities from time to time for taking measurements of some of the craters formed in the natural earth, and for noticing the difference in the action of the shells from the smooth-bored and rifled guns. The craters formed by the shells from the smooth-bores were vastly inferior in point of size to those formed by the shells from the corresponding calibres of rifled guns, and the larger calibres of the latter were equally triumphant over the smaller, that is to say—the craters of the 110 and 70-pounder Armstrong were proportionally very much larger than those of the 40, 20, or 12-pounders, and in a ratio far exceeding the increase of their bursting charges. There was also a very marked difference between the action of the rifle and spherical shells: in the case of the former, the shell seemed to tear a long furrow in its passage previous to explosion, scattering the earth on either side, and on bursting, to uplift and thoroughly disperse a large mass of earth, leaving a large cavity or hollow, whereas the spherical shell appeared merely to bury itself and then raise up a mass of earth, the larger portion of which fell back into the crater. From a careful observation of the craters, and by a comparison of the measurements taken, it was found that, as a rule, the live shell previous to explosion penetrated about two-thirds the distance of the blind shell of the same calibre. During the testing of the fuzes, a few experiments were made in pitching fire, the object being to ascertain whether it is possible to pitch shells fired from rifled guns with low charges, over the crest of a work, and to explode them on the terreplein, represented on this occasion by the cutting in rear of No. 2 earthwork; the practice, however, was so very wild and the

* The cartridges used on these particular occasions were purposely made of different lengths.—W. S. B.

fuzes generally such failures, that the experiment was abandoned without arriving at any satisfactory conclusion.

The next experiment was the breaching of the left flank of No. 2 earthwork, and was commenced on the afternoon of the 3rd September, when 53 rounds, live shell, with full and half charges, were fired, viz. :—

Half Charges.	Rounds.	Full Charges.	Rounds.
40-pounder Armstrong ..	8	110-pounder Armstrong ..	15
110-pounder „ ..	6	70-pounder „ ..	12
	—	68-pounder smooth-bore ..	12
Total ..	14		—
		Total ..	39

I should mention, that previous to this, a dummy gun (of wood) and a dummy detachment had been placed in position in the cutting in rear of the left flank of the earthwork.

The firing was resumed on the following morning, 4th September, at 9 50, and continued at intervals, until 2·13 p.m., as follows :—

	H. M.
Commenced	9·50 a.m.
Ceased	11·0 a.m.
Battery reopened fire	11·30 a.m.
Ceased	12·40 p.m.
Reopened fire	12·57 p.m.
Ceased	1·35 p.m.
Reopened fire	1·40 p.m.
Ceased	2·13 p.m.

The parapet was carefully examined every time the firing ceased, and after 51 rounds had been fired, the effect on the exterior and superior slopes was considerable, several huge cavities having been formed, none of which, however, penetrated to the interior slope; but the terreplein (or cutting in rear) was nevertheless strewn with shell splinters and large lumps of clay, some of which had penetrated the bank in rear to a considerable depth. At 12·40 p.m., after 110 rounds had been fired, the parapet began to present a most dilapidated appearance, and the displacement of earth was much increased. At 1·35 p.m., after 143 rounds had been fired, a hasty examination only was permitted, and it was ascertained that a clear breach had been made with an average depth of 4 feet 6 inches; and at 2·13 p.m., when the firing ceased for the day, the interior of the work was laid quite bare, and a practicable breach formed about 33 feet in width, and 5 feet in depth. The whole of the interior of the work was covered with shell splinters, although the fire was directed only against the left flank. The dummy gun had been struck in several places, and the detachment was quite *hors de combat*. The number of rounds fired on the 4th September, full service charges being used with all guns except the

70-pounders, which fired 12 rounds with 8 lb. charges, were as follows:—

110-pounder Armstrong	.. ..	76 rounds live shell.
70-pounder ,,	.. ..	15 ,, ,,
40-pounder ,,	.. ..	59 ,, ,,
20-pounder ,,	.. ..	15 ,, ,,
10-inch gun	.. ..	6 ,, ,,
Total..	..	171 rounds.

Making a grand total for the two days of 224 rounds, viz.:—

110-pounder Armstrong	.. ..	97 rounds live shell.
70-pounder ,,	.. ..	27 ,, ,,
40-pounder ,,	.. ..	67 ,, ,,
20-pounder ,,	.. ..	15 ,, ,,
10-inch gun	.. ..	6 ,, ,,
68-pounder smooth-bore	.. ..	12 ,, ,,
Total..	..	224 rounds.

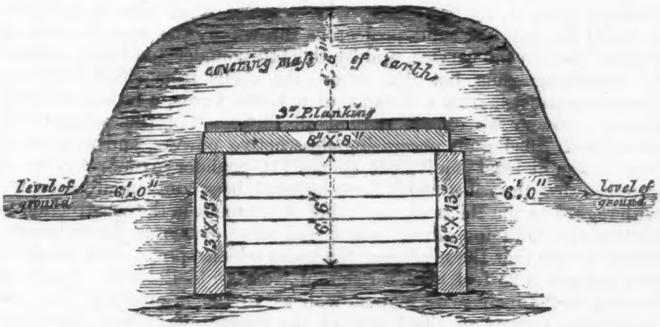
The weight of metal expended in the above was 16,244 lbs., and the amount of powder 3,116 lbs., viz., 1,965 lbs. for charges, and 1,151 lbs. for bursting charges; but if we take into account only the number of rounds which were effective, that is, struck the parapet and burst, viz.:—

110-pounder Armstrong	.. ..	56 rounds live shell.
70-pounder ,,	.. ..	22 ,, ,,
40-pounder ,,	.. ..	43 ,, ,,
20-pounder ,,	.. ..	8 ,, ,,
10-inch gun	.. ..	0 ,, ,,
68-pounder smooth-bore	.. ..	4
Total..	..	133 rounds.

the above expenditure is considerably reduced, and we find that the actual results were produced at a cost of only 9,547 lbs. of metal, and 1,808 lbs. of powder, viz., 1,131 lbs. for charges, and 677 lbs. for bursting charges. The formation of the breach was unquestionably to be attributed to the 76 rounds fired by the 110-pounder Armstrong on the 4th September; the smooth-bores and lesser calibres of rifled guns producing little or no effect on the parapet, which would have resisted their fire for days; during the practice it was observed that those shells which struck somewhat high on the exterior slope produced the greatest effect, and displaced a far greater quantity of earth than those which struck lower, and consequently met with increased resistance from the soil. The time occupied on the 3rd and 4th inst., in forming the breach, was a little over four hours, but when we consider that the damage to the parapet was almost entirely produced by one gun, I think it may fairly be estimated that the same effect could easily be

produced in half that time, and similar results would of course have been still more readily achieved if there had been embrasures in the parapet.

The last eight rounds from the 110-pounder with live shell and full-service charges were fired at a splinter proof near the butts, which had been constructed for the use of the range party; it was hit three times, and reduced to a heap of ruins. The following rough section will serve to give the dimensions; in plan it measured 7 ft. by 6 ft. 6 in.



The results of these experiments generally have assisted in the solution of many important questions, and have also afforded much information that is valuable to the artillery and engineer branches of the service; for instance, we learn that the best mode of breaching an earthwork is by a *direct concentrated* fire of live shells from rifled guns with full-service charges, and that a few HEAVY rifled guns are far more useful for the purpose than a number of the SMALLER calibres. We also find that smooth-bores should never be used against earthworks when rifled guns can be obtained, being infinitely inferior in the most essential points, viz., accuracy of aim and the destructive effects of their shells. It is likewise apparent, that in destroying a parapet, the fire should be directed so as to cut it gradually down from the superior slope to the base. The destructive effects upon the interior of a work, of the splinters from rifle shells, and the wonderful accuracy of aim of the guns of the present day, fully established by these experiments, warn us, that in the construction of batteries likely to be exposed to the fire of rifled guns, additional protection, either by means of traverses or some approved form of blindage must be provided for gun detachments and the guns themselves; it is also very questionable whether in such instances the construction of embrasures should not be altogether prohibited, or at all events, if permitted, a much greater space must be allowed between them than has hitherto been considered sufficient. The mounting of guns en barbette is also objectionable in consequence of the increased exposure of the guns and detachments working them; it seems, therefore, desirable that some

means should be adopted for raising and lowering guns, so that they may appear above the parapet only for the purpose of being fired, the detachment remaining throughout under cover. The facts just recorded are chiefly useful as conveying suggestions for consideration when reviewing the principles and details of attack, where earth necessarily forms the protecting medium, and there are yet one or two points immediately connected with this subject, which I think will not be deemed out of place, and which I now purpose briefly alluding to.

In reverting to the details of the previous pages we find that an ordinary parapet, 25 feet thick, with a relief of 12 feet, is sufficient to resist the heaviest solid projectiles thrown by the smooth-bores at present used in the service, and by the 110-pounder and lesser calibres of Armstrong guns, but that where the shells from rifled guns are directed against it from a distance of a 1,000 yards, a breach is easily formed; now as we expect to find all fortresses of the present day armed with rifled guns possessing destructive powers, and with accuracy of aim at least equivalent to the 110-pounder Armstrong, we at once see that the rules which have hitherto been universally accepted with regard to the thickness and relief of parapets, in the construction of earthworks, both for offensive and defensive purposes, have become obsolete, and that the minimum thickness which should now be given to a parapet is 25 feet, with a relief of from 10 to 12 feet. Again, in looking to the increased range as well as to the accuracy of aim and destructive powers of rifled guns of the present day, fresh difficulties present themselves; we find that the 1st parallel with the batteries usually constructed in it can no longer be established at 600 yards, but will have to be commenced at a much greater distance; that the rate of progress of the saps and approaches will be much slower; that the undefended spaces in advance of a fortress will now be considerably reduced, that a much more extended front will be covered by the fire of its guns, necessitating the occupation of a much greater extent of ground than would have hitherto been found necessary; and there is yet one most important fact we must not lose sight of in consideration of this subject, viz., that the guns of the besieged will be of much larger calibre than those of the besiegers; these are points which tell heavily against the besiegers and their chances of success, when carrying out the details of attacks in accordance with principles which have hitherto proved sound and eminently successful; in fact, the increased difficulties and the vast expenditure of men and means that must now be experienced by a besieging force, are such as to render the question of attack one well worthy of the time and attention of the most competent authorities, with a view to the establishment of general principles for future guidance better suited to the emergencies of the case than those which have hitherto been set forth, but have now become deficient and inapplicable.

No. 1.—Penetration of Projectiles (Solid Shot and Blind Shell) Fired from Rifled Guns into Made Earth.

Nature of Gun.	General No. of Round.	Register No. on Projectile.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Plan of position of projectile.	Penetration.	Nature of soil.	Remarks.
			° ′	lb. oz.					ft. in.		
20-pr. Armstrong	16	7	2 28	2 8	Solid shot	20·387	3·846		10 0	Clay.	
"	19	10	"	"	"	"	"		9 2	"	A ricochet.
"	20	11	"	"	"	"	"		11 9	"	
"	21	12	"	"	"	"	"		10 9	"	
40-pr. Armstrong	23	2	2 0	5 0	Solid shot	41·2	4·846	*	13 9	Clay.	* This shot was found in a perfectly vertical position, with its nose pointing downwards.
"	24	3	"	"	"	"	"		15 5	"	
"	25	4	"	"	"	"	"		13 6	"	
"	26	5	"	"	"	"	"	*	15 6	"	* This shot was found in a perfectly vertical position, with its nose pointing upwards.
"	27	6	"	"	"	"	"		16 4	"	

No. 1.—PENETRATION OF PROJECTILES (SOLID SHOT AND BLIND SHELL) FIRED FROM RIFLED GUNS INTO MADE EARTH.

Nature of Gun.	General No. of round.	Register No. on projectile.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Plan of position of projectile.	Penetration.	Nature of soil.	Remarks.
			° ′	lb. oz.					ft. in.		
70-pr. Armstrong	262	3	2 20	9 0	Solid shot	70·074	6·487	*	6 1	Clay.	* This shot struck a 32-pr. (round No. 40) and was found broken up.
„	263	4	2 24	„	„	„	„		17 0	„	
„	265	6	2 20	„	„	„	„		24 6	„	Entered on superior slope.
„	266	7	2 10	„	„	„	„		13 2	„	
„	267	8	„	„	„	„	„		12 5	„	
„	269	10	„	„	„	„	„		14 3	„	
„	271	12	„	„	„	„	„		14 8	„	
110-pr. Armstrong	28	1	2 40	12 0	Solid shot	111·0	7·095		21 2	Clay.	
„	30	3	„	„	„	„	„		28 1	„	Entered on superior slope.
„	32	5	„	„	„	„	„		20 9	„	

,,	35	8	,,	,,		,,	,,		15 5	,,	Supposed to be a ricochet.
,,	37	10	,,	,,	,,	,,	,,		21 11	,,	
12-pr. Armstrong	..	..	..	..	..	..	..	..	..	..	9 rounds were fired, but all the shell broke up, and no reliable measurement could be taken.
20-pr. Armstrong	106	1	2 35	2 8	Blind shell	21·25	3·846	*	8 7	Clay.	* Found broken up.
,,	107	2	,,	,,	,,	,,	,,		8 9	,,	
,,	108	3	,,	,,	,,	,,	,,		11 3	,,	
,,	109	4	,,	,,	,,	,,	,,	*	8 10	,,	Found broken up.
,,	110	5	,,	,,	,,	,,	,,		13 3	,,	
40-pr. Armstrong	111	1	2 0	5 0	Blind shell	40·398	4·846		11 2	Clay.	
,,	112	2	,,	,,	,,	,,	,,		9 0	,,	
,,	115	5	2 4	,,	,,	,,	,,		11 6	,,	
,,	116	6	,,	,,	,,	,,	,,		13 10	,,	
,,	117	7	,,	,,	,,	,,	,,		12 11	,,	
110-pr. Armstrong	118	1	2 34	12 0	Blind shell	104·723	7·095		13 2	Clay.	
,,	121	4	2 32	,,	,,	,,	,,		18 8	,,	
,,	122	5	,,	,,	,,	,,	,,	*	18 1	,,	* Found in two pieces.
,,	123	6	,,	,,	,,	,,	,,	*	14 11	,,	* Fragments found.
,,	124	7	,,	,,	,,	,,	,,		17 11	,,	

No. 1.—Penetration of Projectiles (Solid Shot and Blind Shell) Fired from Rifled Guns into Natural Earth.

Nature of gun.	General No. of round.	Register No. on projectile.	Elevation.	Charge.	Projectile.			Plan of position of projectile.	Penetration.	Nature of soil.	Remarks.
					Nature.	Mean weight in lbs.	Mean diam. in inches.				
			° ′	lbs. oz.					ft. in.		
20-pr. Armstrong.	73	13	2 35	2 8	Solid shot.	20·387	3·846		1 9	Hard natural concrete.	A ricochet.
”	74	14	”	”	”	”	”		4 5	Hard gravel	
”	75	15	”	”	”	”	”		6 10	”	Passed through a vein of clay before reaching the gravel.
”	76	16	”	”	”	”	”		4 2	”	
	77	17	”	”	”	”	”		5 0	”	
”	78	18	”	”	”	”	”		4 8	”	
40-pr. Armstrong	80	8	2 6	5 0	Solid shot.	41·2	4·846		7 8	Gravelly clay	
”	81	9	”	”	”	”	”		5 0	”	
”	82	10	”	”	”	”	”		8 4	”	

,,	83	11	,,	,,	,,	,,	,,		7 3	,,	
,,	84	12	,,	,,	,,	,,	,,		7 6	,,	
70-pr. Armstrong.	290	14	2 30	9 0	Solid shot.	70·074	6·487		8 6	Hard gravel	
,,	292	16	,,	,,	,,	,,	,,		4 0	Natural concrete	
,,	293	17	,,	,,	,,	,,	,,		6 6	Hard gravel	
110-pr. Armstrong	86	12	2 40	12 0	Solid shot.	111·0	7·095		9 0	Natural concrete	
,,	88	14	,,	,,	,,	,,	,,		9 5	,,	
,,	89	15	,,	,,	,,	,,	,,		9 0	,,	
,,	90	16	,,	,,	,,	,,	,,		11 5	Clay and gravel	
12-pr. Armstrong	68	11	2 10	1 8	Segment shell	10·574	3·074	*	3 0	Gravelly clay	* Fragments found.
,,	69	12	,,	,,	,,	,,	,,	*	3 4	,,	Do.
,,	70	13	,,	,,	,,	,,	,,	*	3 3	,,	Do.
,,	71	14	,,	,,	,,	,,	,,	*	2 0	Natural concrete	Do.
,,	72	15	,,		,,	,,	,,	*	2 0	,,	Do.
20-pr. Armstrong	168	6	2 43	2 8	Blind shell.	21·25	3·846	*	3 10	Hard flinty soil	* Fragments found.
,,	169	7	,,	,,	,,	,,	,,		12 6	Loam	
,,	171	9	,,	,,	,,	,,	,,		6 0	Clay and gravel	

No. 1.—Penetration of Projectiles (Solid Shot and Blind Shell) Fired from Rifled Guns into Natural Earth.

Nature of Gun.	General No. of round.	Register No. on projectile.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Plan of position of projectile.	Penetration.	Nature of soil.	Remarks.
			° ′	lbs. oz.					ft. in.		
20-pr. Armstrong	172	10	2 43	2 8	Blind shell	21·25	3·846		7 0	Clay and gravel	
,,	173	11	,,	,,	,,	,,	,,		8 0	,,	
40-pr. Armstrong	174	8	2 14	5 0	Blind shell	40·398	4·846	*	4 6	Hard gravel	* Fragments found.
,,	175	9	2 14	,,	,,	,,	,,	*	6 6	,,	* Do.
,,	176	10	2 12	,,	,,	,,	,,		5 0	,,	
,,	178	12	2 10	,,	,,	,,	,,		8 5	Stiff clay	
,,	179	13	,,	,,	,,	,,	,,		3 6	Natural concrete	Fragments found.
110-pr. Armstrong	180	8	2 40	12 0	Blind shell.	104·723	7·095		10 6	Clay and gravel	
,,	181	9	,,	,,	,,	,,	,,		7 3	Natural concrete	
,,	182	10	,,	,,	,,	,,	,,		8 3	,,	
,,	183	11	,,	,,	,,	,,	,,		12 10	Stiff clay	
,,	184	12	,,	,,	,,	,,	,,		13 0	,,	

No. 1.—Penetration of Projectiles (Solid Shot and Blind Shell) Fired from Smooth-bored Guns into Made Earth.

Nature of Gun.	General No. of round.	Register No. on projectile.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Penetration.	Nature of soil.	Remarks.
			°	lbs. oz.				ft. in.		
32-pounder ..	38	1	$2\frac{1}{8}$	8 0	Solid shot	31·2	6·17	14 0	Clay	
„	40	3	2	„	„	„	„	5 0	„	This shot was struck by a 70-pr. and found in pieces.
„	44	7	$2\frac{1}{8}$	„	„	„	„	11 9	„	
„	46	9	„	„	„	„	„	12 8	„	
„	49	12	„	„	„	„	„	13 6	„	
68-pounder ..	52	8	$1\frac{1}{8}$	16 0	Solid shot	65·922	7·91	6 10	Clay	A ricochet.
„	58	9	$2\frac{1}{8}$	„	„	„	„	21 6	„	
„	60	11	„	„	„	„	„	21 1	„	
„	63	14	„	„	„	„	„	17 4	„	
32-pounder ..	127	3	2	8 0	Blind shell	23·574	6·17	5 6	Stiff clay	
„	128	4	„	„	„	„	„	8 9	Clay	
„	132	8	$2\frac{1}{8}$	„	„	„	„	8 10	„	
„	133	9	„	„	„	„	„	5 10	Stiff clay	Found in natural soil.
„	134	10	„	„	„	„	„	9 6	Clay	
„	135	11	„	„	„	„	„	3 6	Gravel	A ricochet.
„	136	12	„	„	„	„	„	13 2	Clay	Entered on superior slope.
„	138	14	„	„	„	„	„	10 6	„	
68-pounder ..	144	6	$1\frac{1}{2}$	16 0	Blind shell	50·297	7·85	8 7	Stiff clay	Found in natural soil.
„	148	8	„	„	„	„	„	8 0	„	„
„	150	10	$1\frac{3}{4}$	„	„	„	„	7 3	„	„
„	157	17	„	„	„	„	„	14 10	Clay	
„	160	18	„	„	„	„	„	6 3	Stiff clay	Found in natural soil.
„	165	24	„	„	„	„	„	6 3	„	

No. 1.—Penetration of Projectiles (Solid Shot and Blind Shell) Fired from Smooth-bored Guns into Made Earth.

Nature of guns.	General No of round.	Register No. on projectiles.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Penetration.	Nature of soil.	Remarks.
			°	lbs. oz.				ft. in.		
8-inch gun ..	140	1	$2\frac{3}{4}$	8 0	Blind shell	50·297	7·85	21 0	Clay	Entered on superior slope.
,,	142	3	,,	,,	,,	,,	,,	11 11	,,	
,,	147	11	,,	,,	,,	,,	,,	11 6	,,	
,,	155	14	,,	,,	,,	,,	,,	10 5	,,	
,,	159	21	,,	,,	,,	,,	,,	10 7	,,	
,,	166	30	,,	,,	,,	,,	,,	12 9	,,	
,,	167	29	,,	,,	,,	,,	,,	12 0	,,	
10-inch gun ..	274	3	$2\frac{7}{8}$	12 0	Blind shell	83·898	9·84	9 5	Stiff clay	Found in natural soil.
,,	277	6	,,	,,	,,	,,	,,	12 0	Clay	
,,	280	9	,,	,,	,,	,,	,,	11 5	,,	
,,	284	13	,,	,,	,,	,,	,,	10 11	,,	
,,	288	17	,,	,,	,,	,,	,,	11 3	,,	

No. 1.—Penetration of Projectiles (Solid Shot and Blind Shell) Fired from Smooth Bored Guns into Natural Earth.

Nature of gun.	General No. of round.	Register No. on projectile.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Penetration.	Nature of soil.	Remarks.
			°	lbs. oz.				ft. in.		
32-pounder ..	91	13	$2\frac{3}{8}$	8 0	Solid shot	31·2	6·17	4 6	Gravelly clay	
,,	92	14	,,	,,	,,	,,	,,	3 0	Hard gravel	
,,	96	18	$2\frac{1}{4}$	,,	,,	,,	,,	5 0	Gravelly clay	

"		97	19	"	"	"	"	"	3	0	Hard gravel	
"		98	20	"	"	"	"	"	2	0	"	
68-pounder	..	99	18	2¼	16 0	Solid shot	65·922	7·91	13	0	Stiff clay	
"		100	19	2⅜	"	"	"	"	6	8	Hard gravel and concrete	
"		101	20	"	"	"	"	"	5	6	"	
"		102	21	"	"	"	"	"	6	2	"	
"		104	23	"	"	"	"	"	7	0	"	
"		105	24	"	"	"	"	"	4	8	"	
"		55	6	2⅛	"	"	"	"	11	0	Stiff clay	Fired at artificial butt.
"		56	7	"	"	"	"	"	13	4	"	"
"		57	8	"	"	"	"	"	12	1	"	"
"		59	10	"	"	"	"	"	13	4	"	"
"		62	13	"	"	"	"	"	12	1	"	"
32-pounder	..	186	17	2¼	8 0	Blind shell	23·574	6·17	2	6	Hard gravel	
"		189	20	"	"	"	"	"	2	6	"	
"		190	21	"	"	"	"	"	3	6	"	
"		191	22	"	"	"	"	"	2	3	"	
68-pounder	..	201	42	1⅞	16 0	Blind shell	50·297	7·85	4	0	Hard gravel	
"		202	43	"	"	"	"	"	4	0	"	
"		203	44	"	"	"	"	"	4	0	"	
"		204	45	"	"	"	"	"	7	0	Stiff clay	
"		205	46	2	"	"	"	"	4	0	Hard gravel	
"		206	47	"	"	"	"	"	11	4	Clay	
"		207	48	"	"	"	"	"	4	0	Hard gravel	
8-inch gun	..	192	25	2⅞	8 0	Blind shell	50·297	7·85	1	0	Hard gravel	A ricochet.
"		194	31	3	"	"	"	"	4	2	"	
"		196	33	"	"	"	"	"	6	2	Grav. and clay	
"		197	34	"	"	"	"	"	3	0	Hard gravel	
"		198	35	"	"	"	"	"	3	6	"	
10-inch gun	..	295	19	3	12 0	Blind shell	83·898	9·84	4	0	Natural concrete	Blind shell.
"		296	20	"	"	"	"	"	3	9	"	

No. 1.—PENETRATION OF PROJECTILES (SOLID SHOT AND BLIND SHELL) FIRED FROM SMOOTH-BORED GUNS INTO MADE EARTH.

Nature of guns.	General No of round.	Register No. on projectiles.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Penetration.	Nature of soil.	Remarks.
			°	lbs. oz.				ft. in.		
8-inch gun ..	140	1	$2\frac{3}{4}$	8 0	Blind shell	50·297	7·85	21 0	Clay	Entered on superior slope.
,,	142	3	,,	,,	,,	,,	,,	11 11	,,	
,,	147	11	,,	,,	,,	,,	,,	11 6	,,	
,,	155	14	,,	,,	,,	,,	,,	10 5	,,	
,,	159	21	,,	,,	,,	,,	,,	10 7	,,	
,,	166	30	,,	,,	,,	,,	,,	12 9	,,	
,,	167	29	,,	,,	,,	,,	,,	12 0	,,	
10-inch gun ..	274	3	$2\frac{7}{8}$	12 0	Blind shell	83·898	9·84	9 5	Stiff clay	Found in natural soil.
,,	277	6	,,	,,	,,	,,	,,	12 0	Clay	
,,	280	9	,,	,,	,,	,,	,,	11 5	,,	
,,	284	13	,,	,,	,,	,,	,,	10 11	,,	
,,	288	17	,,	,,	,,	,,	,,	11 3	,,	

No. 1.—PENETRATION OF PROJECTILES (SOLID SHOT AND BLIND SHELL) FIRED FROM SMOOTH BORED GUNS INTO NATURAL EARTH.

Nature of gun.	General No. of round.	Register No. on projectile.	Elevation.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diam. in inches.	Penetration.	Nature of soil.	Remarks.
			°	lbs. oz.				ft. in.		
32-pounder ..	91	13	$2\frac{3}{8}$	8 0	Solid shot	31·2	6·17	4 6	Gravelly clay	
,,	92	14	,,	,,	,,	,,	,,	3 0	Hard gravel	
,,	96	18	$2\frac{1}{4}$	,,	,,	,,	,,	5 0	Gravelly clay	

,,	97	19	,,	,,	,,	,,	,,	3	0	Hard gravel	
,,	98	20	,,	,,	,,	,,	,,	2	0	,,	
68-pounder ..	99	18	2¼	16 0	Solid shot	65·922	7·91	13	0	Stiff clay	
,,	100	19	2⅜	,,	,,	,,	,,	6	8	Hard gravel and concrete	
,,	101	20	,,	,,	,,	,,	,,	5	6	,,	
,,	102	21	,,	,,	,,	,,	,,	6	2	,,	
,,	104	23	,,	,,	,,	,,	,,	7	0	,,	
,,	105	24	,,	,,	,,	,,	,,	4	8	,,	
,,	55	6	2⅛	,,	,,	,,	,,	11	0	Stiff clay	Fired at artificial butt.
,,	56	7	,,	,,	,,	,,	,,	13	4	,,	,,
,,	57	8	,,	,,	,,	,,	,,	12	1	,,	,,
,,	59	10	,,	,,	,,	,,	,,	13	4	,,	,,
,,	62	13	,,	,,	,,	,,	,,	12	1	,,	,,
32-pounder ..	186	17	2¼	8 0	Blind shell	23·574	6·17	2	6	Hard gravel	
,,	189	20	,,	,,	,,	,,	,,	2	6	,,	
,,	190	21	,,	,,	,,	,,	,,	3	6	,,	
,,	191	22	,,	,,	,,	,,	,,	2	3	,,	
68-pounder ..	201	42	1⅞	16 0	Blind shell	50·297	7·85	4	0	Hard gravel	
,,	202	43	,,	,,	,,	,,	,,	4	0	,,	
,,	203	44	,,	,,	,,	,,	,,	4	0	,,	
,,	204	45	,,	,,	,,	,,	,,	7	0	Stiff clay	
,,	205	46	2	,,	,,	,,	,,	4	0	Hard gravel	
,,	206	47	,,	,,	,,	,,	,,	11	4	Clay	
,,	207	48	,,	,,	,,	,,	,,	4	0	Hard gravel	
8-inch gun ..	192	25	2⅞	8 0	Blind shell	50·297	7·85	1	0	Hard gravel	A ricochet.
,,	194	31	3	,,	,,	,,	,,	4	2	,,	
,,	196	33	,,	,,	,,	,,	,,	6	2	Grav. and clay	
,,	197	34	,,	,,	,,	,,	,,	3	0	Hard gravel	
,,	198	35	,,	,,	,,	,,	,,	3	6	,,	
10-inch gun ..	295	19	3	12 0	Blind shell	83·898	9·84	4	0	Natural concrete	Blind shell.
,,	296	20	,,	,,	,,	,,	,,	3	9	,,	

No. 2.—Table Showing Mean Penetrations of Projectiles (Solid Shot and Blind Shell) Fired from Rifled and Smooth-bored Guns into Made Earth. (Abstracted from Table 1).

Nature of Gun.	Charge.	Projectile. Nature.	Projectile. Mean weight in lbs.	Projectile. Mean diameter in inches.	Soil.	Mean penetration.	Total mean penetration.
	lbs. oz.					ft. in.	ft. in.
20-pr. Armstrong	2 8	Solid Shot	20·387	3·846	Clay	10 10	10 10
40-pr. do.	5 0	do.	41·2	4·846	do.	14 11	14 11
70-pr. do.	9 0	do.	70·074	6·487	do.	14 4	14 4
110-pr. do.	12 0	do.	111·0	7·095	do.	21 3	21 3
32-pr. Smooth-br.	8 0	do.	31·2	6·17	do.	13 0	13 0
68-pr. do.	16 0	do.	65·922	7·91	do.	19 11	19 11
12-pr. Armstrong	1 8	Segment Shell	10·574	3·074	do.	4 0	4 0*
20-pr. do.	2 8	Blind Shell	21·25	3·846	do.	11 1	11 1
40-pr. do.	5 0	do.	40·398	4·846	do.	11 8	11 8
110-pr. do.	12 0	do.	104·723	7·095	do.	16 8	16 8
32-pr. Smooth-br.	8 0	do.	23·574	6·17	do.	9 5	9 5
68-pr, do.	16 0	do.	50·297	7·85	do.	14 10	14 10
8-inch gun.	8 0	do.	50·297	7·85	do.	11 6	11 6
10-inch do.	12 0	do.	83·898	9·84	do.	11 5	11 5

* The fragments only were found, and no accurate measurements could be taken, so this penetration must be considered as approximate only.

No. 2.—Table Showing Mean Penetrations of Projectiles (Solid Shot and Blind Shell) Fired from Rifled and Smooth-bored Guns into Natural Earth. (Abstracted from Table No. 1).

Nature of Gun.	Charge.	Projectile.			Soil.	Mean penetration.	Total mean penetration.
		Nature.	Mean weight in lbs.	Mean diameter in inches.			
	lbs. oz.					ft. in.	ft. in.
20-pr. Armstrong	2 8	Solid Shot.	20·387	3·846	Hard Gravel	4 7	4 7
40-pr. do.	5 0	do.	41·2	4·846	Gravelly Clay	7 2	7 2
70-pr. do.	9 0	do.	70·074	6·487	Hard Gravel	7 6	5 9
do.	..	do.	..	..	Natural Concrete	4 0	
110-pr. do.	12 0	do.	111·0	7·095	Natural Concrete	9 2	10 3
do.	..	do.	..	..	Clay and Gravel	11 5	
32-pr. Smooth-br.	8 0	do.	31·2	6·17	Gravelly Clay	4 9	3 9
do.	..	do.	..	..	Hard Gravel	2 8	
68-pr. do.	16 0	do.	65·922	7·91	Hard Gravel	6 0	9 3
do.	..	do.	..	..	Stiff Clay	12 6	
12-pr. Armstrong	1 8	Segment Shell	10·574	3·074	Gravelly Clay	3 2	2 7
do.	..	do.	..	..	Natural Concrete	2 0	
20-pr. do.	2 8	Blind Shell	21·25	3·846	Gravelly Clay	7 0	5 5
do.	..	do.	..	..	Hard Flinty Bed	3 10	
40-pr. do.	5 0	do.	40·398	4·846	Hard Gravel	5 4	
do.	..	do.	..	..	Stiff Clay	8 5	5 9
do.	..	do.	..	..	Natural Concrete	3 6	
110-pr. Armstrong	12 0	do.	104·723	7·095	Natural Concrete	7 9	
do.	..	do.	..	..	Gravelly Clay	10 6	10 5
do.	..	do.	..	..	Stiff Clay	12 11	
32-pr. Smooth-br.	8 0	do.	23·574	6·17	Hard Gravel	2 8	2 8
68-pr. do.	16 0	do.	50·297	7·85	Hard Gravel	4 0	
do.	..	do.	..	..	Stiff Clay	*7 3	7 6
do.	..	do.	..	..	Clay	11 4	
8-inch gun	8 0	do.	50·297	7·85	Hard Gravel	3 7	4 10
do.	..	do.	..	..	Gravelly Clay	6 2	
10-inch gun	12 0	do.	83·898	9·84	Natural Concrete	3 10	6 7
do.	..	do.	..	..	Stiff Clay	†9 5	

* Including for average rounds, Nos. 144, 148, 150, 160, 165.
† See Round No. 274.

Abstract of Penetrations from Table No. 2.

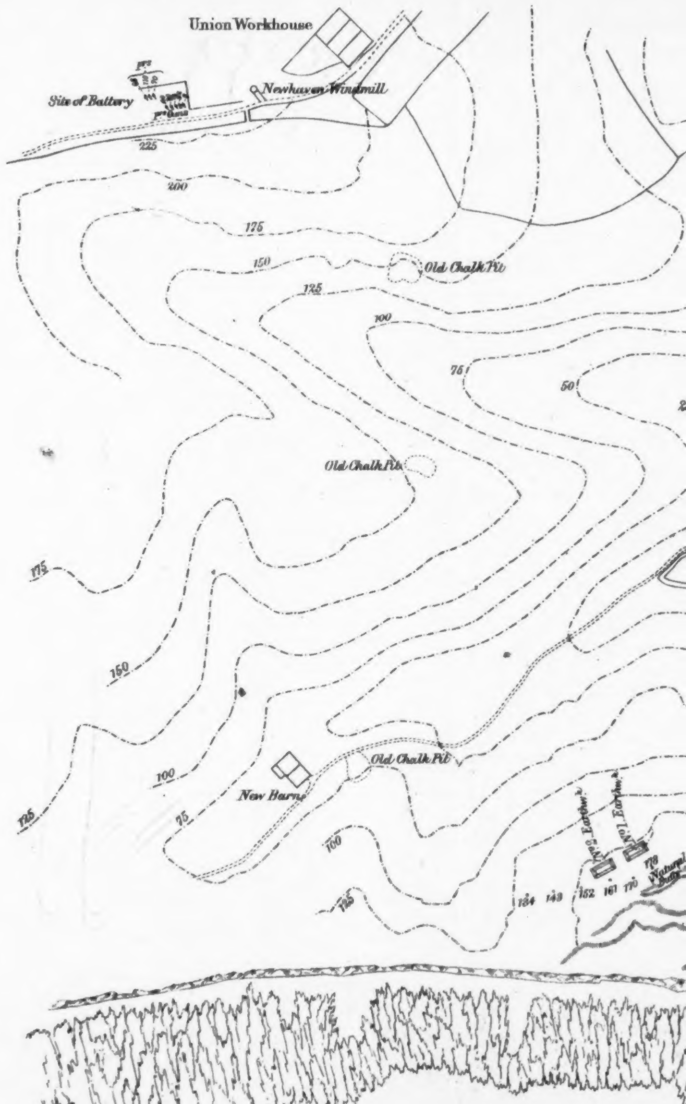
Nature of Gun.	Solid shot into made earth.	Blind shell into made earth.	Solid shot into natural earth.	Blind shell into natural earth.
	ft. in.	ft. in.	ft. in.	ft. in.
110-pounder Armstrong	21 3	16 8	10 3	10 5
70 do. do.	14 4	Nil.	5 9	Nil.
40 do. do.	14 11	11 8	7 2	5 9
20 do. do.	10 10	11 1	4 7	5 5
12 do. do.	Nil.	4 0	Nil.	2 7
10-inch Gun	Nil.	11 5	Nil.	6 7
8-inch Gun	Nil.	11 6	Nil.	4 10
68-pounder smooth-bore	19 11	14 10	9 3	7 6
32-pounder smooth-bore	13 0	9 5	3 9	2 8

No. 3.—TABLE OF FUZES SHOWING RESULTS.

Nature of Gun.	No. of Rounds fired.	Charge.	Nature of Fuze.	Burst. Good.	Burst. Premature.	Burst. Blind.	Total failures.	Proportion of failures in every 10 fuzes.
		lbs.						
20-pr. Armstrong	6	2·5	Service Pillar R L 79	5	0	1	1	1·6
do.	15	2·5	Service Pillar R L 98 M	10	0	5	5	3·3
40-pr. Armstrong	11	5·0	Service Pillar R L 79	10	0	1	1	·9
do.	20	5·0	Service Pillar R L 98 M	13	0	7	7	3·5
do.	6	2·5	do. do.	4	0	2	2	2·5
do.	3	2·5	Service Pillar E.O.C.P.	2	0	1	1	3·3
do.	1	1·25	do. do.	0	0	1	1	10·0
do.	35	5·0	Sensitive Pillar	35	0	0	0	0·0
do.	5	2·5	do. do.	4	0	1	1	2·0
do.	4	1·25	do. do.	0	0	4	4	10·0
do.	17	5·0	Screw Percussion	13	0	4	4	2·3
do.	5	1·25	do. do.	2	0	3	3	6·0
do.	3	1·25	Pettman's Sea Service	0	0	3	3	10·0
70-pr. Armstrong	3	9·0	Service Pillar R L 79	3	0	0	0	0·0
do.	3	9·0	Service Pillar R L 98 M	3	0	0	0	0·0
do.	12	8·0	do. do.	12	0	0	0	0·0
do.	12	9·0	Pettman's Sea Service	8	0	4	4	2·5
110-pr. Armstrong	17	12·0	Service Pillar R L 79	8	9	0	9	5·3
do.	10	10·0	do. do.	5	1	4	5	5·0
do.	10	9·0	do. do.	5	0	5	5	5·0
do.	35	12·0	Service Pillar R L 98 M	29	0	6	6	1·7
do.	4	6·0	do. do.	0	0	4	4	10·0
do.	45	12·0	Service Pillar E.O.C.P.	36	3	6	9	2·0
do.	5	9·0	do. do.	5	0	0	0	0·0
do.	3	6·0	do. do.	0	0	3	3	10·0
do.	2	2·875	do. do.	0	0	2	2	10·0
do.	26	12·0	Sensitive Pillar	17	4	5	9	3·4
do.	8	6·0	do. do.	6	0	2	2	2·5
do.	2	2·875	do. do.	0	0	2	2	10·0
do.	15	12·0	Screw Percussion	5	0	10	10	6·6
do.	2	2·875	do. do.	0	0	2	2	10·0
32-pr. smooth-br.	11	8·0	Pettman's Land Service	7	0	4	4	3·6
68-pr. smooth-br.	20	16·0	do. do.	13	0	7	7	3·5
8-inch gun	7	8·0	do. do.	0	0	7	7	10·0
10-inch gun	6	12.0	do. do.	2	0	4	4	6·6

NOTE.—In the column headed "Nature of Fuze":—
R. L. stands for Royal Laboratory.
M. " for Moorsoon's Composition.
E.O.C. " for Elswick-Ordnance Company.
The Nos. 79 and 98 denote the brand of the fuze.

ROUGH SKETCH, Showing Site of Batter



e of Battery and Artificial and Natural Butts.

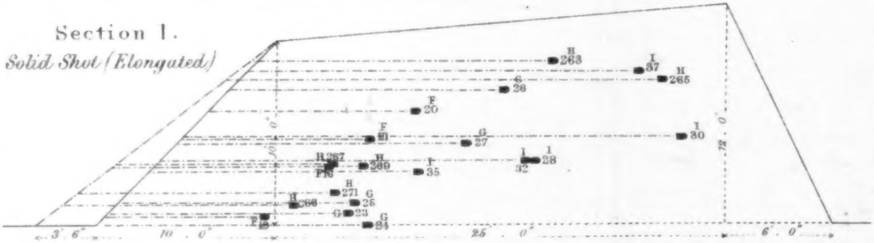
W. Boileau,
Captn. R.E.

J.R Jobbins.

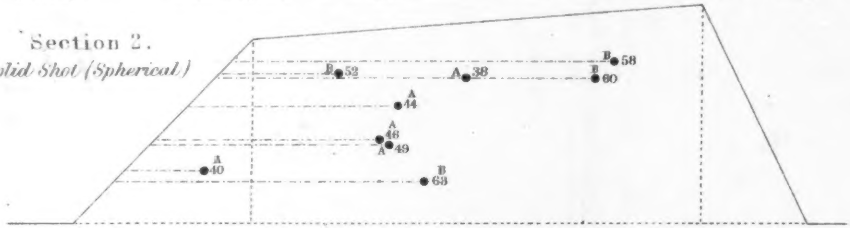
TABLE OF REFERENCE.			
Guns	Solid Shot	Blind Shell	Shot represented
32 Pr.	A	a	38 . 40 . 44 . 46 . 49 128 . 132 . 134 . 136 . 138
68 „	B	b	52 . 58 . 60 . 68 144 . 150 . 157 . 160 . 165
8 Inch		c	140 . 147 155 . 159 . 166 . 167
10 „		d	274 . 277 . 280 . 284 . 288
20 Pr. Armstrong	F	f	16 . 19 . 20 . 21 106 . 107 . 108 . 109 . 110
40 „ „	G	g	23 . 24 . 25 . 26 . 27 111 . 112 . 115 . 116 . 117
70 „ „	H		263 . 265 266 . 267 . 269 . 271
110 „ „	I	i	28 . 30 . 32 . 35 . 37 118 . 121 . 122 . 123 . 124

PLAN, SECTIONS AND ELEVAT[IO…]

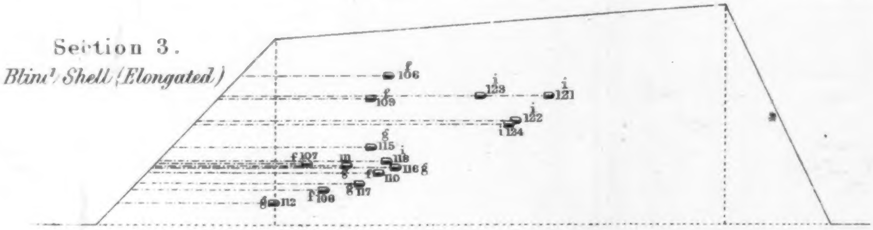
Section 1.
Solid Shot (Elongated)



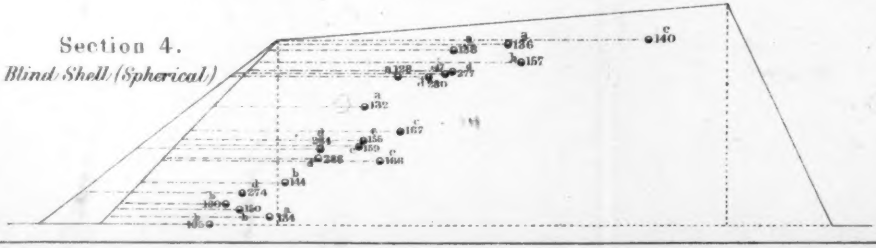
Section 2.
Solid Shot (Spherical)

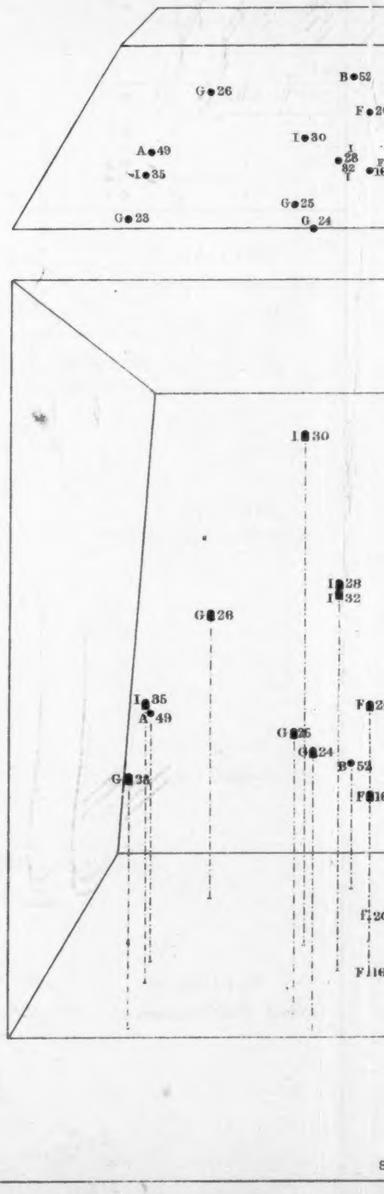


Section 3.
Blind Shell (Elongated)

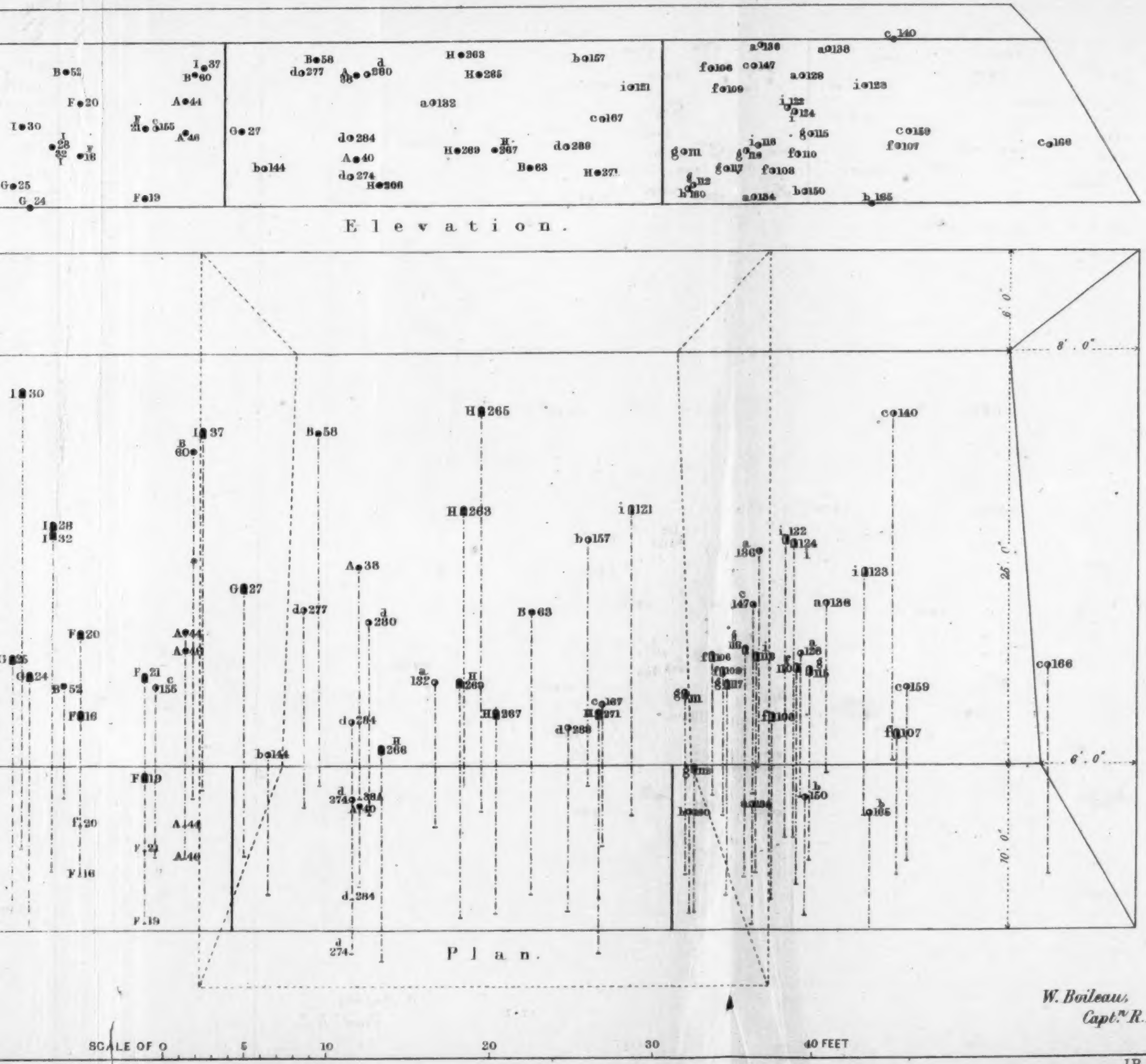


Section 4.
Blind Shell (Spherical)





ELEVATI ON OF ARTIFICIAL PARAPET OR BUTT, SHEWING PENETRATION OF PROJECTILES.



W. Boileau,
Captn. R.E.

J.R. Jobbins.

PLAN AND ELEVATION OF NATURAL BUTT, SHEWING PENET

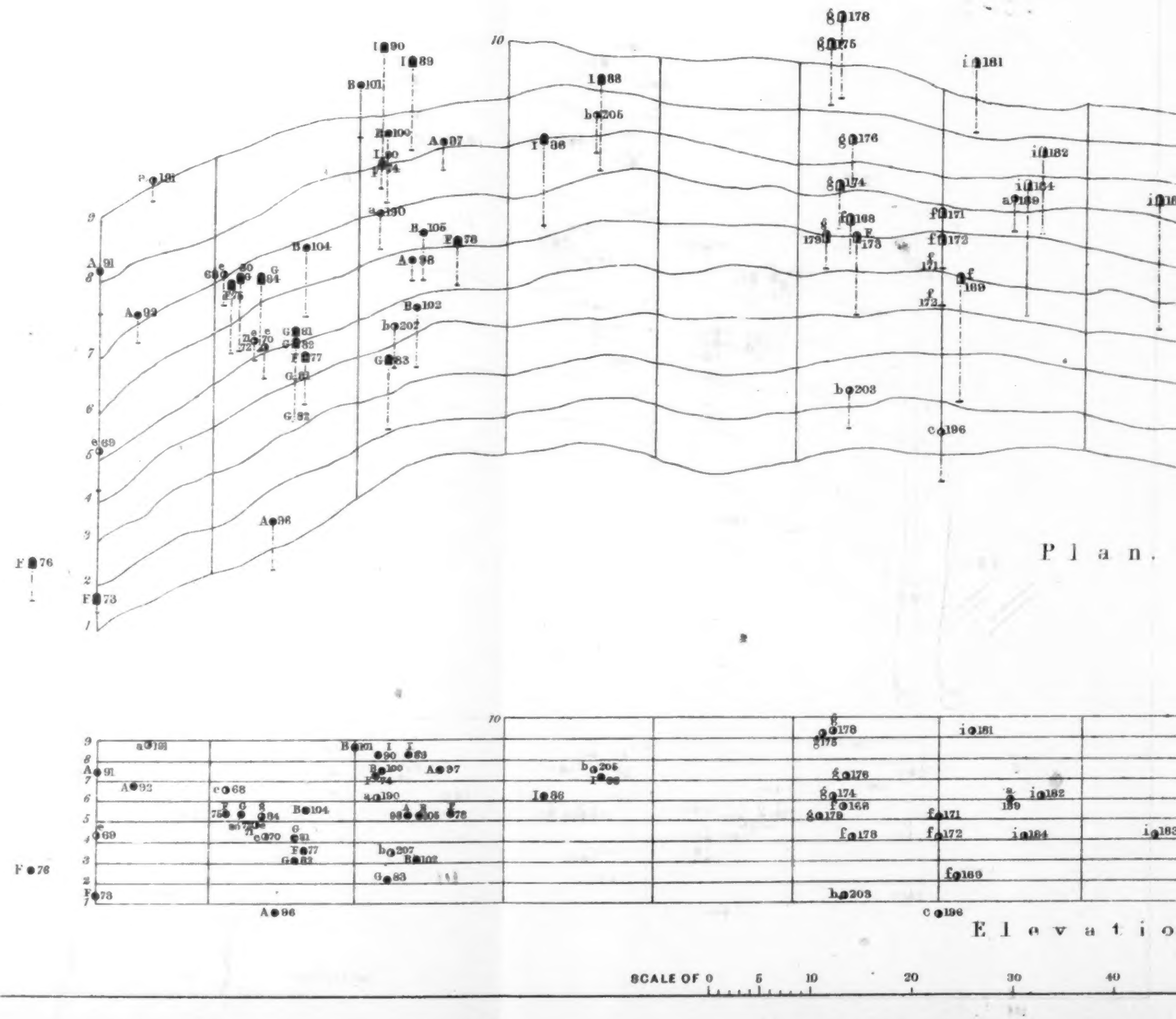
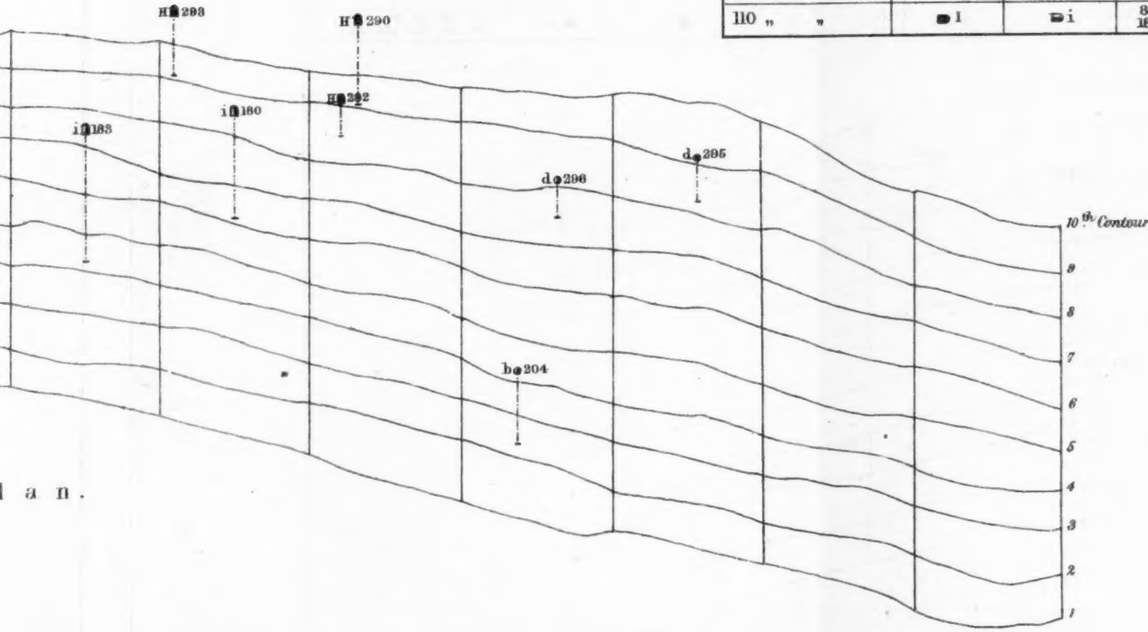
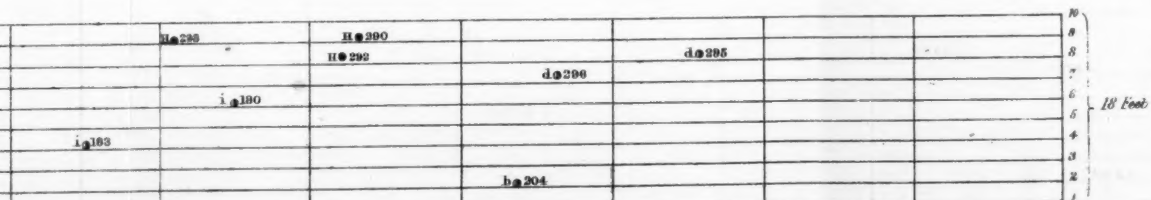


TABLE OF REFERENCE.			
Guns	Solid Shot	Blind Shell	Shot represented
32 Pr.	A	a	91 . 92 . 96 . 97 . 98 . 189 . 190 . 191 .
68 "	B	b	100 . 101 . 102 . 104 . 106 . 203 . 204 . 205 . 207 .
8 Inch		c	196 .
10 "		d	295 .. 296 .
12 Pr. Armstrong		e	68 . 69 . 70 . 71 . 72 .
20 " "	F	f	73 . 74 . 75 . 76 . 77 . 78 . 168 . 169 . 171 . 172 . 173 .
40 " "	G	g	80 . 81 . 82 . 83 . 84 . 174 . 175 . 176 . 178 . 179 .
70 " "	H		290 . 292 . 293 .
110 " "	I	i	86 . 88 . 89 . 90 . 180 . 181 . 182 . 183 . 184 .

PENETRATION OF PROJECTILES.



l a n.

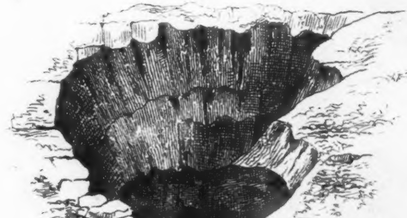


a t i o n

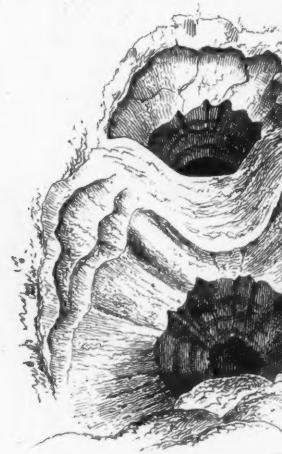
W. Boileau
Captn. R. E.

J.R. Jobbins

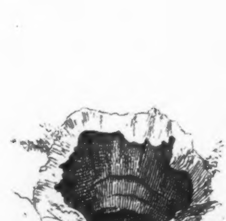
SKETCHES OF SHELL



General Round 233. 110 Pr.
Lateral effect ..... 10. 6"
Vertical effect .... 9. 0"
Soil, Clay & Gravel



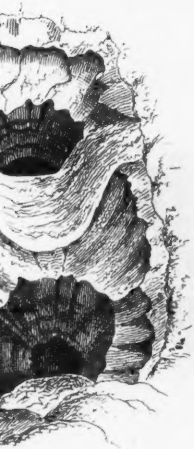
General Rounds 211. 213.
211 { *Lateral effect 3. 9"* *Vertical effect 7. 3"* *Soil, Stiff Clay*
213 { *Lateral* *Vertical* *Soil, Sti*

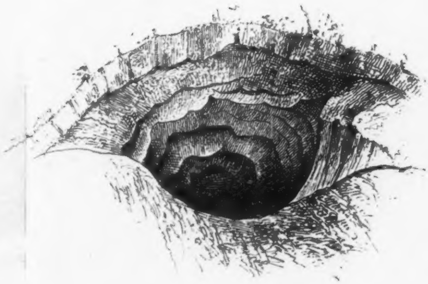


General Rounds 226. 227. 20 Pr.
220 { *Lateral effect 3. 6"* *Vertical effect 3. 9"* *Soil Hard Gravel*
227 { *Lateral effect 3. 0"* *Vertical effect 4. 0"* *Soil Gravel & Clay*

General Round 241. 110
Lateral effect ..... 2. 3"
Vertical effect ...... 8. 0"
Soil Concrete & Loam

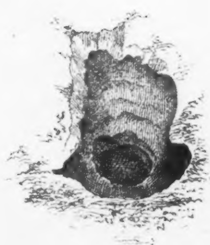
SHELL CRATERS.





General Round 251. 110 Pr.
Lateral effect ..... 9'. 9"
Vertical effect ...... 8'. 9"
Soil Clay & Sand

...nds 211. 213. 40 Pr.
213- *Lateral effect 4'. 3"*
Vertical effect 7'. 8"
Soil, Stiff Clay



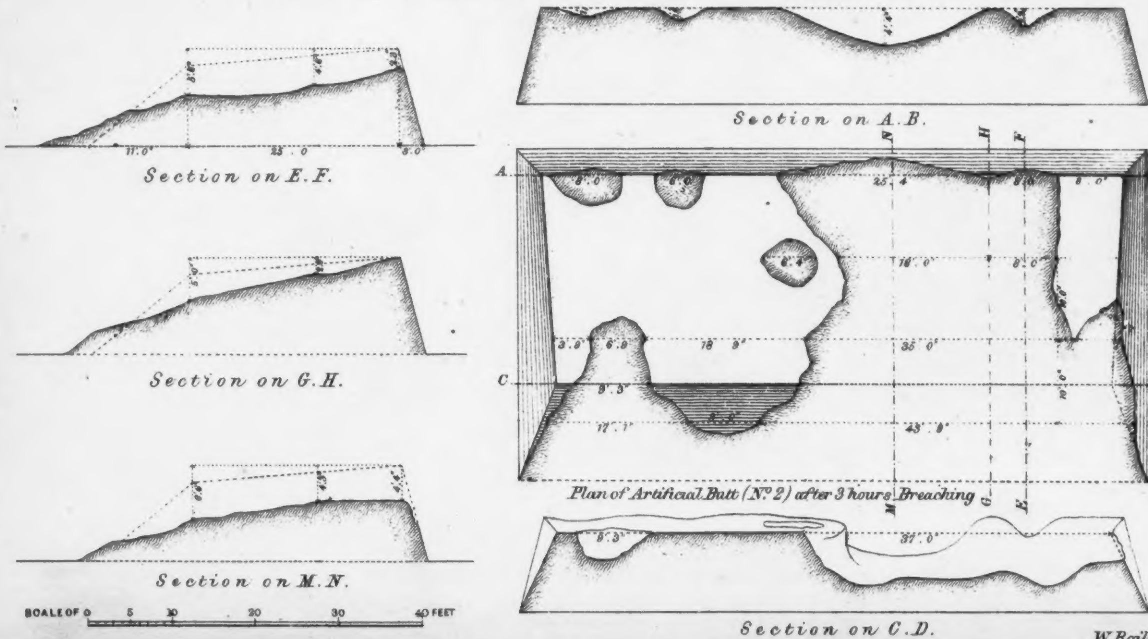
General Round 301. 32 Pr.
Lateral effect ...... 1'. 6"
Vertical effect .... 3'. 3"
Soil very Hard Gravel

...und 241. 110 Pr.
...ffect ..... 2'. 3"
...ffect ...... 8'. 0"
...crete & Loam

W. Boileau,
Captn. R.E.

J.R Jobbins

Plan and Sections of Artifical Parapet or Butt, shewing Breach.



W. Boileau,
Captn. R.E.

J.R.Jobbins